THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY DECEMBER 1989 £1.50

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BUG

SLIDE/TAPE SYNC PROJECT

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AUDIO · COMPUTING · MUSIC · DOMESTIC

December 1989

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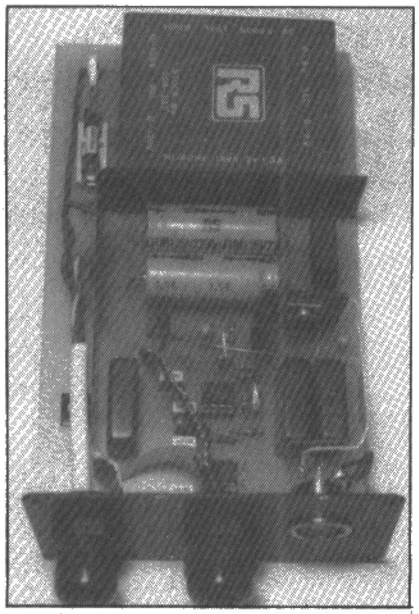

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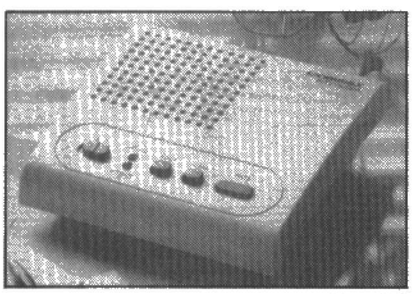

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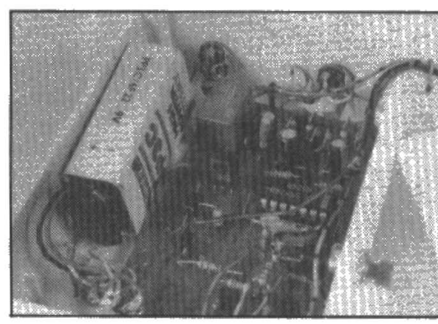

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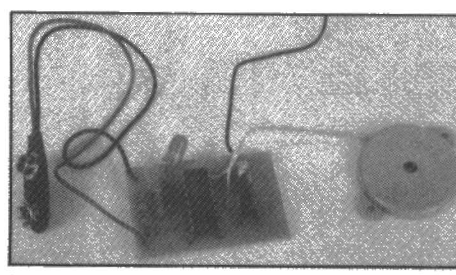

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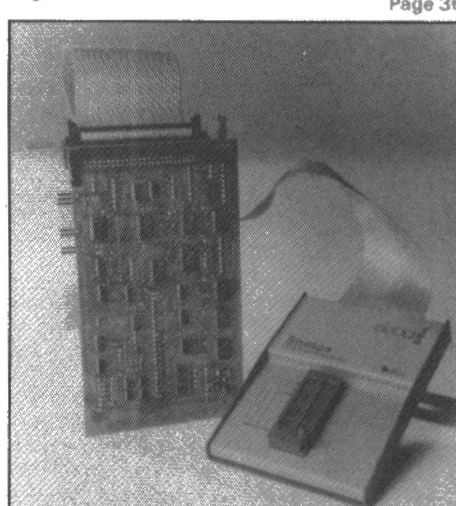
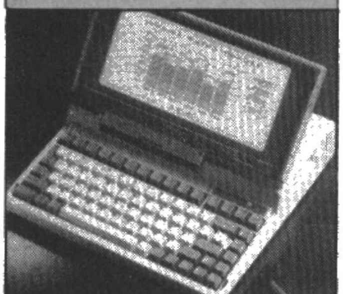


NEWS

MORE LAP-TOP COMPUTERS



The portable and lap-top computer war has now started and the signs are that we shall see some fierce competition between manufacturers in the coming year.

Joining the battle in the marketplace is Psion, the UK based microcomputer manufacturer. Psion, well known for its pocket organisers, has announced a series of portable computers. They are about the size of A4 notepaper, have a full size keyboard and weigh in at just under 2kg. Psion's main advantage will be on the battery life giving up to 60 hours on one set of batteries. Prices will range from £626 to £1720.

Apple Computers, hot on the trail, has announced the release of a new portable. It's distinct advantage will be in the display area.

Many liquid crystal displays lack high contrast and fast response, something which resulted in the user having to work in low level light conditions and waiting for the cursor to catch up. Apple's answer to this is an 'active matrix' LCD screen where every one of the 256,000 pixels is controlled by a transistor giving a more immediate response on the screen. The technology for making such a screen has been difficult and few Japanese manufacturers are undertaking the task.

With battery life of approximately 10 hours and weighing 16llbs, the complete Apple Mac portable should cost around £4,000.

A colour LCD screen laptop computer could steel the show in the next year and that's where Hitachi come in. They have released the HL4000C with an 'active matrix' 6.3in display that produces graphics and text in 8 colours. Plans are also underway for a 10in screen next year. This IBM-PC compatible machine can hold 1Mbyte of memory, and is expandable up to 20Mbytes with hard disc. Battery life is perhaps a slight drawback with only three hours of operation. The HC4000C will cost £3995.00.

SPEECH SYNTHESIZERS

VSI Electronics, distributor for NEC, has announced the 775X range of single chip speech synthesizers.

Higher quality is now achieved using an internal adaptive differential pulse code modulation algorithm. The algorithm produces a digital waveform as low as 16kb/s, a marked improvement over other methods of synthesis. Messages can be encoded faster and would involve simpler and cheaper hardware to augment the chip.

Support for the chips are available in the form of a PC plug in card which comes complete with a microphone and speaker for recording and reviewing.

For further information Tel: (0279) 35477.

PRIVATISATION DELAY

At last the Government has admitted the shortcomings of its plans to privatise the electricity industry. The entire operation has been delayed by six months in an attempt to formulate realistic schedules and a package that city investors will accept.

The two primary failings of Government plans have been the speed at which plans have been pushed through, and the inclusion of nuclear plants in the sale. The U-turn of removing Magnox reactors from the sale (ETI News October) has not been enough to reassure investors. The risk and apparent unpredictability of all nuclear operation (and decommissioning in particular) has rendered the whole enterprise open to doubt.

Further compromise has come with the announcement that the area distribution boards are to be granted a monopoly for four years. Originally the generating companies were to be allowed to poach customers from the boards and supply direct. Now this is to be abandoned, with only the largest companies being allowed to leave the area boards.

The junior energy minister Michael Spicer has explained that this monopoly is to allow more competition in the field of distribution, giving the area boards more security in placing contracts with independent generators.

Interviewed on the BBC's *Newsnight* programme he played down the delay, saying that the privatisation "is a massive reform with tremendous benefits. A delay of six months is neither here nor there in the wide sweep of history." The Government's target was originally, and remains now, to privatise before the next election.

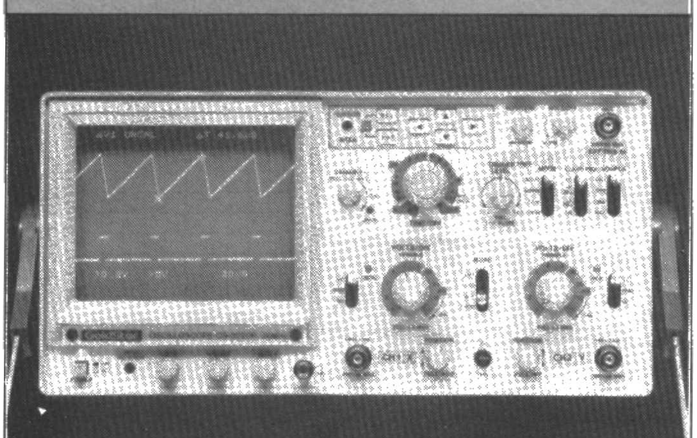
The monopoly of area boards will certainly make their floatation, now set for Autumn 1990, a more profitable proposition. It also ridicules the Government's cornerstone of competition and a free market.

Tony Blair, Labour's Energy Spokesman, points out that "the proposals are now totally different to those before parliament. There is no virtual competition at all. Domestic consumers remain captive to the monopoly area boards, not able to be pinched by generators as proposed. Most important, ordinary domestic customers were told there would be competition and there is none, no opportunity to change boards if dissatisfied. And all this on top of a 15% price increase, the nuclear tax and the huge cost of the sale."

The Government continues to assert that privatisation will still be completed during the lifetime of this parliament. Whether there is any hope of the huge number of generation contracts being signed before the area boards' sale remains to be seen, as the ground rules have only recently been set.

The new schedule puts the launch of National Power and Powergen well into the run-up for the next election, giving this privatisation (twice the size of the gas floatation) a huge electoral importance. Considering the widespread (some would say virtually unanimous) opinion that this sale is continuing solely under the steam of Conservative dogma, the Government appears to be risking its majority on a poorly prepared operation.

SCOPE FOR TEXT



The latest oscilloscope from Alpha Electronics enables waveform settings and measured values to be displayed on the screen.

Model OS8020R has mobile on screen cursors which make it easy to obtain a direct readout of voltage, time and frequency without the need for time consuming calculations.

Apart from this time saving facility the dual trace scope has a 20MHz bandwidth, a sensitivity of 1mV/div and sweep speed of 100ns/div.

This latest scope, including two switched probes, retails for £563.50.

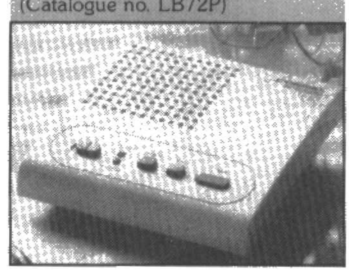
Further information from Quiswood Ltd, 3 Brackenley Court, Brackenley Lane, Embsay, Skipton, N. Yorks BD23 6PX Tel: (0756) 69737.

TALKBACK

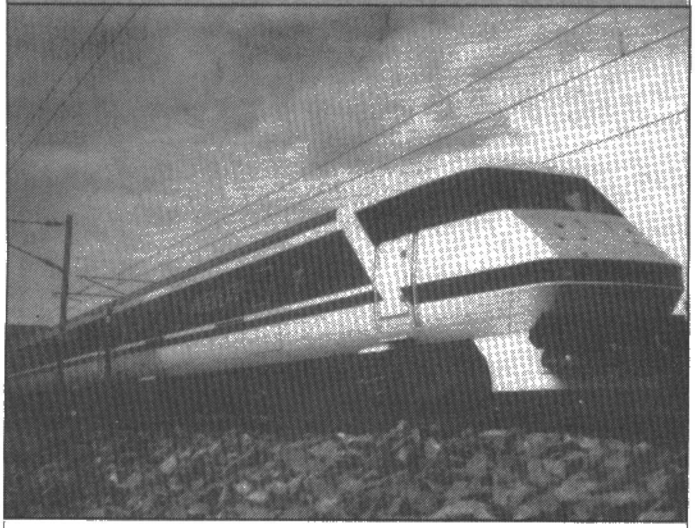
If you've wondered how an intercom could be set up in your home without the need to trail wires everywhere, then a Maplin FM wireless intercom could be the answer (you also have the chance to win one in this issue).

The 2-channel high quality intercom transmits and receives its signal through the mains household wiring using an FM signal on frequencies of 110kHz and 140kHz. The light beige units can be wall or desk mounted and are only available in pairs.

The (YT16S) 2 channel intercom retails at £24.95 inc VAT. A budget master/slave version, ideal for baby sitting is available at 9.95 inc VAT (Catalogue no. LB72P)



BR GETTING THERE



Rail travel speeds are scheduled for an increase. British Rail plans to start operating a 140mph service by 1993 on the London to Edinburgh route.

The high speeds have been brought about by the introduction of a new class of locomotive rolling stock.

The Intercity 225 as it's known has already started service on the King's Cross route but is limited at present to a maximum speed of 125mph and in also terminates at Leeds. BR engineers are still working on the electrification of the line from Leeds to Edinburgh, and the final phase is planned for completion by May 1991.

Full 140mph working will not commence until the Automatic Train Protection system (ATP) is installed into the locomotives. This will ensure that the train will automatically stop in the event of passing a red light without permission.

Experimental versions of ATP will be installed into locomotives on West country routes next year.

The speeds contemplated in this country stand in direct contrast to developments in Japan and West Germany where Maglev trains at great expense will reach speeds of 500kph (312mph).

Photo courtesy of InterCity.

WORLD'S SMALLEST CAMCORDER

Sony has launced the worlds smallest and lightest video camera/recorder weighing just under 800g.

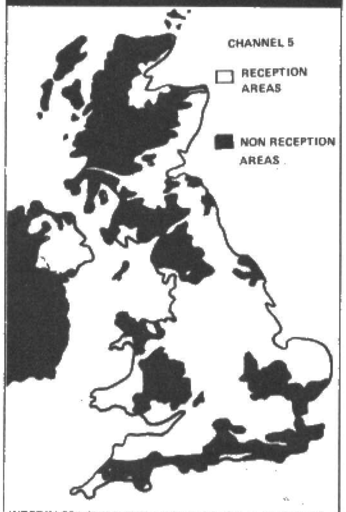
The CCD-TR55 is a 'palm-sized' camcorder ideally suited for travel use fitting easily into a travelbag.

Features include, a six times zoom lens, digital superimpose with scrolling, a variable speed shutter down to 1/4000th of a second and a fader for both sound and picture.

Its small size is achieved using the latest computer aided design technology to ensure that no space was left unused. Even the microphone is an integral part of the body.

The CCD-TR55 will retail at £999.95.

CHANNEL 5



INTERIM FREQUENCY PLAN SUBJECT TO MODIFICATION

Channel 5, the new national television network could face difficulties from the commercial point of view when it opens in 1993.

The publication of transmitter area coverage from the DTI has revealed large gaps in populated regions of the south east and could lead to an unwillingness from the commercial world to advertise to a somewhat limited audience.

The reason for the limited coverage is one of interference from Irish, French and Belgian broadcasts but limited power output and careful channel selection would avoid this. An estimated 70% of the population can be covered with 25 transmitters on channels 35 and 37 but a problem remains because these channels will interfere with the standard video recorder on channel 36. This would mean that video cassette recorders would have to be retuned and the cost for an engineer to carry this out would have to be borne by the franchise holder.

LE PLUG

A Hertfordshire inventor has come up with a novel design for a mains adaptor converting the two pin Euro plug to a British three pin type.

Doubtless, there have been many times when you've cursed buying a piece of electrical equipment with a moulded two pin plug on the end. Kitchen-table surgery seems to be only answer involving the severence and reconnection of the normal three pin British device. Or it may have been resulted in the inevitable screwdriver job in the earth hole to allow the insertion of this new device.

The connection is beautifully simple. Open up the three pin plug, place the two pin moulded fitting in and screw up the back plate.

The adoption of such a plug could simplify production runs of electrical goods for internal and European markets.

Further information from Le Plug. Tel: (0763) 89268.

VIDEO EDITOR

A table-top video editor and image corrector is now available to give your home video a more professional finish.

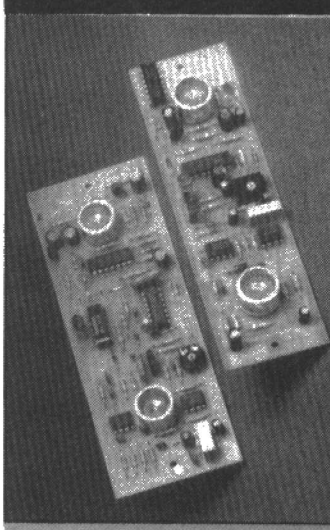
The Portax VEO-100, marketed by Hanimex, is a compact console which combines infra-red remote control, audio editing and image correction. It can store and recall up to 100 sequences and so would appeal to camcorder users and amateur film makers who can put their creative ideas into practice, cutting first and correcting on-stream.

The built in video corrector can be used independently to change colour, brightness, contrast, sharpness and sound. Other features include a frame-by-frame picture search with facilities to delete or interchange sequences, and a second audio track to mix down background music and voice overs.

When editorial of the tape is complete, as many copies can be taken as required. The retail price is £1,495.00.

For further information Tel: (0225) 783016.

ULTRASONIC DETECTORS



Autona has launched two new ultrasonic detectors which can be incorporated into many electrical applications to save energy or provide security.

Typical applications might be in the operation of light switches, automatic door opening, water control and as warning devices.

The devices will detect movement between five and seven metres, provide a high level of immunity with three levels of discrimination, incorporate an exit delay and timed alarm period and operate from 12V. The transmitters are crystal controlled for stability and this also allows several units to be operated without interaction.

For further information contact Autona Ltd. Tel: (08444) 5740.

READ\WRITE

ETI LETTERS

Relative problems

I enjoyed your article on relativity in July's ETI, but isn't there a direct contradiction with Quantum Theory here? Quantum Theory states that atoms can change (energy) state instantly. Quantum Theory does not allow for one point of an atom to start changing first, and the rest to follow an 'all change' message permeating at the speed of light.

As atoms do occupy a measurable volume of space, I fail to understand. Doesn't the Big Bang theory depend on relativity and Quantum Mechanics, and where does this leave it?

Please explain.

Yours sincerely

Andrew Werner
Liverpool

The problem here perhaps is in even considering the change of state as somehow involving a motion in space. If the event is truly instantaneous then there is no communication between parts of the atom, there is no starting point from which the change spreads because it happens simultaneously at all points. Nothing travels — and going no distance in no time is certainly not excluded by relativity.

But the questioner is right to point out some of the uncertainties where relativity and quantum mechanics meet. There is a quantum interconnectedness in the universe that we cannot as yet explain.

This is demonstrated in the following experiment. First find a radioactive substance that gives out paired photons (gamma rays) in opposite directions (these paired photons have exactly the same quantum numbers and a shared random polarization). This may sound a tall order but happily there is one.

Set up polarising filters either side of your source, the further away the better. With the filters in the same orientation measure the arriving photons. This will give you a random sequence of hits and misses: the photon either passes through or is blocked. Compare the sequences from the two ends and they're the same.

Nothing surprising so far. Now move one of the filters through 10° and check the sequences again. As you would expect there are now a few discrepancies between the two ends. But if we now alter the polarizer by 30° we find more discrepancies than we should. The paired photons are somehow linked and what ever we do to one of the pair affects the outcome at the other end of the apparatus.

This would indeed be remarkable if it were of any use but once again this quantum fuzziness squeezes in through the gaps in relativity without endangering its stability at all. For though the paired photons appear to be in some sort of faster-than-light communication we cannot discover the discrepancy without comparing the two sets of results which involves slower than light communication (and who is to say that comparing the results is not part of the process itself). Without comparing the sequences, all we are left with is a random series of hits and misses that has been altered in some indeterminate way — ie a random series of hits and misses. Not much of a message in that.

Woolly information on Cardigan Island

Reading the October issue of ETI, page 10, I was very impressed by the thought that your magazine was devoting time, energy and money to the excellent conservation programme on Cardigan Island.

You can imagine how disappointed I became when I came across a piece in *Electronic Times* (enclosed). I think it would be nice if you gave some of the credit where it is apparently due, ie Peter Lees and most of all Racal!

Yours faithfully

A P Kersey
Toddington, Beds.

Now hold on there! The equipment to be operated on Cardigan Island has many parts. Racal is providing only the recorder that will be used for sourcing the shearwater birdsong, Deta/Leda is donating the batteries, someone else the solar panels and so on. ETI with Andrew Armstrong has designed, built and donated the amplifier that uses the power from the battery-backed cells to amplify Racal's cries. No easy task and all our work! Presumably the Electronics Times piece started life as a Racal press release, and all credit to them. Hopeful we have all enjoyed and benefitted from our involvement and with any luck the shearwaters will agree. But credit where credit is due!

Response from the cabinet

I eagerly turned to Jeff Macauley's article in July's ETI. It is always good to have design information on loudspeakers instead of the usual 'woodwork plans'. However, a few things do not make sense!

From the formulae in the article the optimum cabinet volume V_b is 0.517cu ft and the port length 7.55in. Note the maths for the port length uses f_t and not f_b as published.

Now, if you go back to one of the best articles ever published in ETI, Barry Porter's bass design piece in April 1984, his formulae are not only different but the results are totally different!

V_b is now 0.42cu ft, f_b = 49Hz and the port length 7.8in.

I would put it that the two boxes will sound completely different. The ports are similar but one 'optimum' cabinet is 20% bigger than the other! This would make tuning it a farce, and use an awful lot more wood. While manufacturing tolerance is to be expected, 20% seems very strange.

Who is right? Can you get either writer to explain?

A footnote — I see Barry Porter used metric values. Five years on we go back to imperial — so much for 1992!

Let's have more practical audio articles especially on speaker design. Keep up the good work.

Regards,

Rick Hughes,
Clydach, Swansea.

Jeff Macauley replies: At first sight the equations do seem so totally different that they would produce entirely different enclosure performance.

Luckily I have at my disposal a complete Theille/Small program 'Boxresponse'. This predicts the response of any enclosure given appropriate parameters (as used by JBL amongst others).

Using both sets of equations I ran the Micromonitor woofer data to produce the alignments as follows:

Barry Porter's:

V_{opt} = 0.143 cu ft
f_{-3dB} = 67.6Hz
f_b = 63.73Hz

Mine:

V_{opt} = 0.0169 cu ft
f_{-3dB} = 62.1Hz
f_b = 59Hz

When run through the program there's about 1dB in it! Mine is about 1dB up on Barry's. More interestingly I used both sets of equations to see how the Micro Monitor comes out.

By Barry's:

f_{-3dB} = 63.4Hz
f_b = 60.8Hz

By mine:

f_{-3dB} = 64.7Hz
f_b = 61Hz

So close that the response predictions are within 0.1dB. It seems that both sets of equations are valid, the only difference being the predicted volumes.

As for dimensions, try asking your local wood merchant to cut imperial-sized wood into metric sizes. The reaction I got was unprintable! My formulae will in any case work with metric figures since they are based on the ratio of V_{as} to V_b.

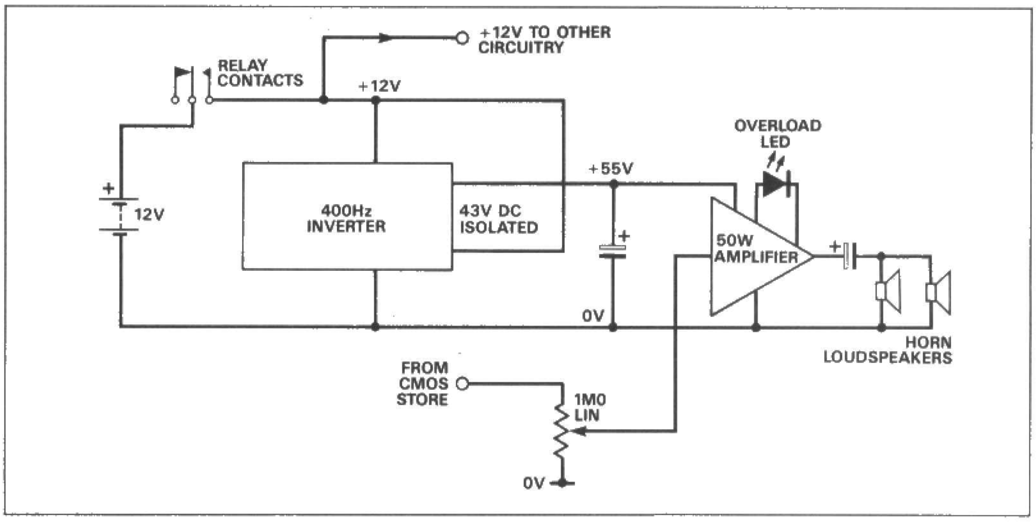
Several port dimension formula are available, none of which (in my experience) give the correct length. The one I've quoted has produced the best results for me.

As a matter of interest the best method for really accurate results is to measure f_b by holding a sound level meter next to the cone and adjusting the input frequency for maximum output. To be effective the port has to be an inch or so longer than predicted to produce a slightly low f_b, and then trimmed, repeating the measurement until the required result is produced. In practice this is unnecessary — quite small variations in temperature and air pressure will change the tuning by a Hz or so.

Lastly (but by no means leastly) one has to consider the effect of the listening room. Most of us have parallel walls so live in a naturally resonant environment. These resonances or eigentones occur mainly below 100Hz. The result is peaks and troughs of several dB in this range even assuming perfect speakers!

BLUEPRINT

The story so far: the Manx shearwater sea-birds were wiped from their colony on Cardigan Island when a shipwreck brought a plague of rats to the island. Now that the rats have been removed the shearwaters would be safe to return, but attempts to import them from another sanctuary have failed. Rod and his friends at the Dyfed Wildlife Trust decide that this is because the island is too quiet. They conceive a cunning plan to fool the birds into thinking there are flocks of mating shearwaters on the island. They get a recorder from Racal, batteries from Data/Leda and solar cells from BP. Now all they need is an amplifier. Enter ETI, the Blueprint column, and Andrew Armstrong.



This month I am able to report that the 12V powered high output amplifier is built and tested. It has been disassembled sufficiently to be sent to the Dyfed Wildlife Trust, where it can be mounted in its case and the final wiring attached.

Little change to the original design by John Linsley Hood is required, because a timing circuit controlling a relay is already present in the system so that electronic switching is not needed. Protection for the battery is, as I had expected, provided in the charging control unit, so that the circuit need not have provision to switch itself off if the battery voltage falls.

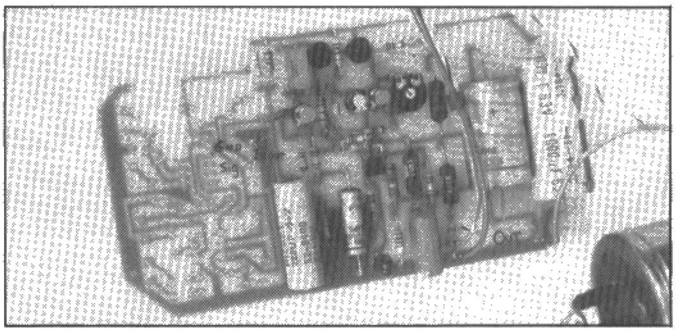
Inverter

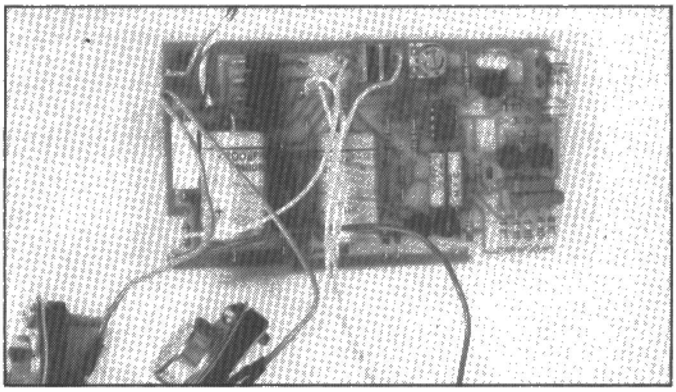
The 12V to 55V voltage converter was the first item to construct, because I have no 55V bench power supply to test the amplifier. I have, however, an adequate 12V supply to run the inverter.

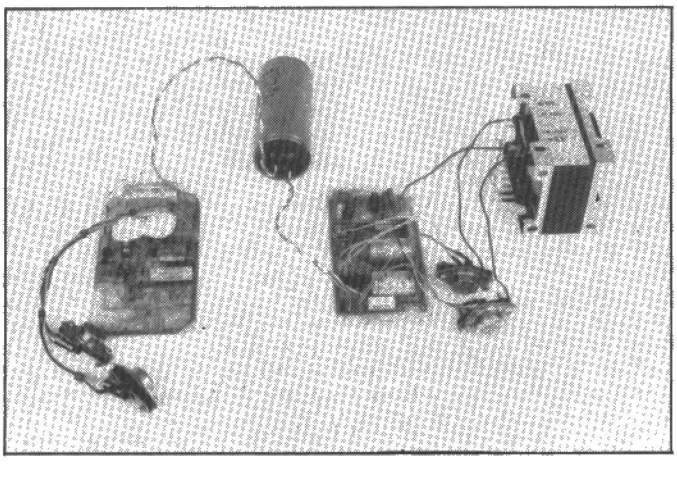
The design of the inverter is well suited to its task, and needs no obvious modification. There is a progressive start-up capacitor in the circuit, so that switch-on transients will not be a problem. In building the unit, I made several trivial component substitutions, including the use of 4700μ decoupling capacitors on the PCB instead of 2200μ as specified, simply because this value was available at the time. The extra decoupling will cause no problem, and may improve the performance marginally.

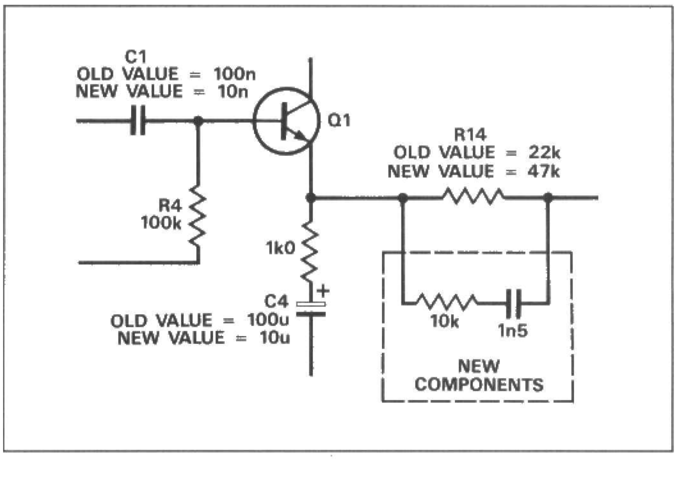
The specified type of driver transistor, the BD537, does not appear in any of my catalogues, so I used TIP31A transistors which work very well and do not get hot.

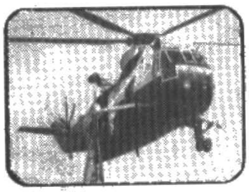
On test the unit worked reliably into a dummy load consisting of a 100R metal clad resistor on a heatsink (drawing about 30W) for several hours. The 2N3055s, on a small temporary heatsink, ran cool. This is as it should be because they are switching and thus should dissipate

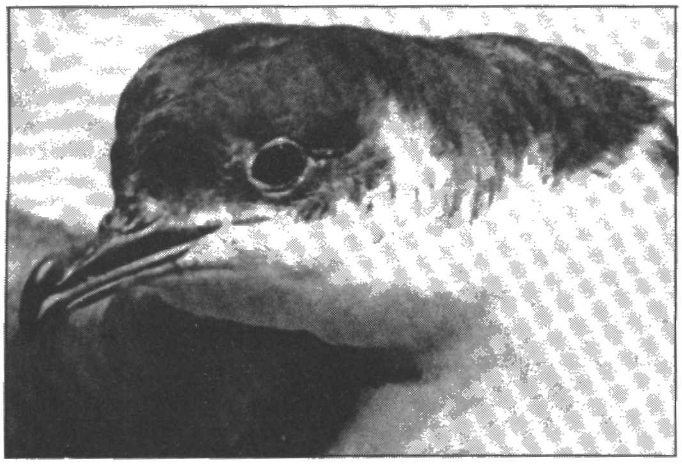












little power. When assembled into the case, the power transistor will rely on the case as a heatsink.

Power Amplifier

In some respects the specification of the power amplifier exceeds the requirement. The design, published in ETI May 1986, includes a two channel mixer/preamplifier which is not needed in this application, and which adds to wiring complexity. The power amplifier itself delivers marginally less than the requested 60W, and is of almost hi-fi quality. Given the limited bandwidth required to reproduce the call of the Manx shearwater, some reduction of bandwidth may be acceptable if it gives other advantages.

The amplifier was initially built as shown in the original design, with the exception that the preamplifier components were omitted, and a 100μ capacitor was used to couple to the loudspeakers instead of the specified 2200μ capacitor, because frequency response down to the normal lower audio limit is not required.

The amplifier worked correctly as first built, but the gain was not quite high enough to guarantee full output from the signal level expected from the CMOS audio store. However, because the full bandwidth of the amplifier is not needed it would be reasonable to increase its gain. This would increase distortion, particularly at high frequencies, but there is adequate gain at the lower frequencies required in this application

The feedback resistor was increased from 22k to 47k, approximately doubling the voltage gain, and extra feedback components were added to roll off the gain at high frequencies to minimise the chance of unwanted out-of-band digital noise from the CMOS store causing problem.

Low frequency response was cut by reducing the value of the input coupling capacitor from 100n to 10n. This should minimise the effect of the inevitable DC step applied to the input at switch on. To speed the settling of the amplifier at switch on, and because the 100μ capacitor used for initial testing was physically too large for the PCB, the value of C4 was reduced to 10μ. This further restricts the low frequency gain of the amplifier at frequencies too low to be of interest to our feathered friends.

Final Testing

The whole system was connected together, with a sinewave generator connected to the input and a dummy load connected to the output. The output waveform was displayed on an oscilloscope. First of all the quiescent current was adjusted to eliminate visible crossover distortion on a 2kHz waveform at full output. In order to see the effects of distortion clearly, the oscilloscope Y gain and timebase were adjusted to magnify a small portion of the waveform around the zero crossing. The quiescent current was then left at the minimum level for no visible distortion.

On full output signals it was observed that the signal clipped on negative half cycles earlier than on positive ones. The overload indicator detects clipping only on positive half cycles, so that negative half cycle distortion could occur without indication. In addition, asymmetrical clipping wastes power, because the output must be reduced until both half cycles do not clip. Fine adjustment of the output voltage of the inverter equalised the clipping levels, and completed the functional testing. An initial soak test of one day at 40W output was carried out to check reliability, and further soak testing will be carried out after assembly into the casework in Dyfed.

I look forward to being able to report, probably next year, on the success of the project.

Andrew Armstrong

BOOK LOOK

Challenger —
A Major Malfunction
Malcolm McConnell
Published by Unwin/Hyman
£3.95 paperback

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(paperback due in February)

In January 1986, the space shuttle *Challenger* lifted off from the launch pad at Cape Canaveral in Florida. It was a cold morning — NASA had never launched in such cold conditions — and the cold was to be fatal to the crew. Seventy seconds after lift-off, the shuttle exploded.

In 1969, even before the first men had landed on the moon, NASA was planning to go to Mars. To do that, they needed a space station orbiting the Earth. To build that, they needed the space shuttle.

'Challenger — A Major Malfunction' is written by Malcolm McConnell, a journalist covering the Space programme. It goes right back to the to the conception of the shuttle. In a detailed (but never dull) account he explains that the theory was for cheap routine access to space. What NASA got was the result of compromise and politics. The shuttle was supposed to be cost-effective, so it had to fly frequently; this resulted in great pressure to launch. If future missions were not to be delayed (and these included observation of Halley's Comet), Challenger had to be launched in January. Safety criteria changed — in the previously relaxed flying schedules, the question was 'is it safe to launch?'. It now became 'is it unsafe to launch?'.

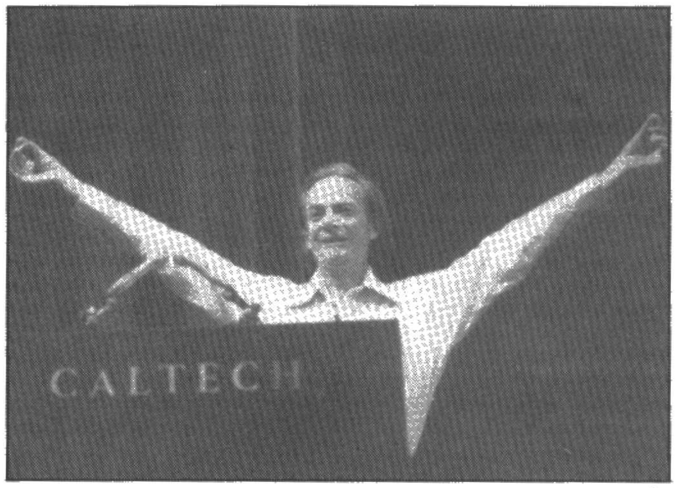
The importance of this change of emphasis was demonstrated by the Morton Thiokol company. They made the solid-fuel rocket boosters (SRBs) which were basically giant fireworks strapped on either side of the shuttle to give extra power at lift-off. Some engineers were concerned about the joints between the sections of the SRB — under the pressures of launch, the joints deformed slightly. Two circular rubber rings were relied upon to expand and seal the gap that formed — but under extremely cold conditions, they might not expand quickly enough; hot exhaust gases could escape, and disaster could follow.

So the engineers argued. Tragically they were overruled by management. Morton Thiokol gave a 'go for launch'.

The Rogers Commision was set up to investigate the accident and Professor Richard Feynman was asked to join.

Richard Feynman (who died last year) was one of the great characters of science. He was a Nobel prizewinner (see ETI Sept 1988), and yet he never lost a childlike sense of wonder. His methods were unorthodox and he certainly did not fit in well with rules or committees. For these reasons, he was at first unwilling to join the commission. Then his wife pointed out that "if you don't do it, there will be twelve people all going round from place to place together. But if you do join the commission, there will be eleven people all in a group, going around from place to place together, while the twelfth one runs around all over the place, checking all kinds of unusual things". Feynman took up the position.

The first half of his book *'What Do You Care What Other People Think?'* is taken up with stories from his early life, illustrating the kind of person he was — a continuation of the earlier volume of dictated memoirs 'Surely You're Joking Mr Feynman'. This is by



no means exclusively scientific — it includes Feynman's chat-up techniques and constant pranks (often at the expense of bureaucracy).

The other half is his account of his work on the Rogers Commission. Feynman writes in an informal, chatty style (he refers to Neil Armstrong as 'the moon man') which makes very easy reading, even when he is dealing with highly complex subjects. The book contains many photographs and diagrams and gives a very thorough account of how the members of the Commission waded through ambivalence and double-talk to track down the cause of the shuttle disaster. Together, *'Challenger, A Major Malfunction'* and *'What Do You Care What Other People Think?'* provide a full account of the events leading up to, and the investigation of, the Challenger disaster.

Bill Shaw

Robert Penfold is pretty prolific with his processor and lately the world of MIDI music has been his principal topic. His two volumes — *Practical MIDI Handbook* and *Synthesizers For Musicians* might be expected to contain a fair amount of duplication. After all a synth design these days is unlikely to get further than the downtown Tokyo trash tip unless it has a comprehensive MIDI spec to present to the punters.

How could Mr Penfold attempt to separate the two subjects without making both books a few quavers short of a full bar? Let us see.

The Practical MIDI Handbook was reviewed in ETI August 1988. It attempts to be a catch-all study of the MIDI standard and its applications — a knowledge base on which to build the machine specifics.

The meat of the book is the chapters describing modes, codes and message formats where prospective MIDI software programmers can sink their teeth into the business of message making.

The rest of the book goes downhill somewhat with somewhat basic explanations of microprocessors and controllers.

Overall then the novice will gain a good solid grounding in the world of MIDI. The expert might feel a bit short on technicalities and specifics but will nevertheless find the *Practical MIDI Handbook* a useful reference tool and teaching guide.

Synthesizers For Musicians
Robert Penfold
Published by PC Publishing

OK let's be honest now, raise your hand if you know how Casio's phase distortion synthesis actually works? And Roland's LA techniques? Yamaha's FM synthesis? How about good old fangled analogue synths . . . do you know your DFC from your VCO?

This really is an excellent book, it sorts everything out and leaves you wondering why on earth the manufacturers didn't just say this in the first place. It starts off very basic with sound and pitch in general, then goes on to analogue synthesis. Although one might regard analogue as old hat (though don't say that in front of Mr Oberheim), an understanding of the techniques here teaches you how sounds are shaped and added together. Armed with this knowledge you can progress to 'modern synthesis' and it all falls together with startling simplicity.

The style, as with the MIDI Handbook, is easily read and in a non-technical form of address while imparting quite technical wisdom. Plenty of pics (from the Penfold CAD workshop) keep the clarity constant and you come out wondering why there was such a fuss about FM being hard to handle. Of course there is no substitute for hands-on programming and it is likely that when you return to your voice-editiing package things will still go wrong, but at least you may now comprehend the reasons why!

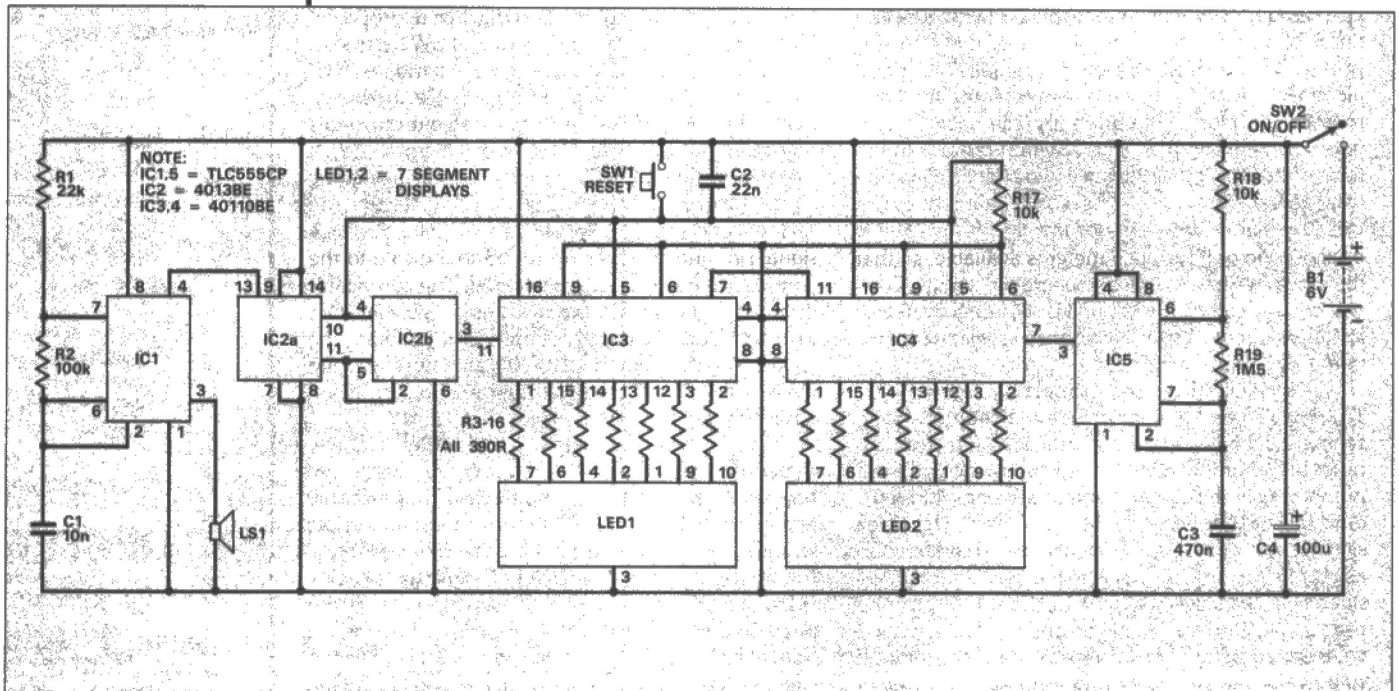
Penfold also tackles samplers with consummate ease but then wastes a chapter on how to choose the keyboard you need. When this was followed by a description of different effects units I almost decided that the book has ended back with the samplers and the rest could be subtitled "Pad, pad, pad . . ." In actual fact the stuff on effects is most instructive, particularly with regard to the changeover from analogue footpedals to digital rack processors.

All in all then *Synthesizers For Musicians* is an excellent read and well worth the money. Oddly the almost total omission of MIDI (2 pages total) doesn't seem to matter at all. This makes the *Practical MIDI Handbook* an ideal companion volume, useful for reference although not quite such an interesting read.

Pip Loukes

GAMES TECH TIPS

COUNTDOWN GAMES TIMER



Robert Penfold creates a few electronic novelties for the festive season

A games timer can be used when playing any game that tends to drag sometimes due to players taking too long to make their moves. The basic idea is that when someone makes their move they reset the timer, and it starts a new timing run. The next player must make his or her move before the timing run ends, or a suitable penalty (loss of a turn, having to read E.T.I. from cover to cover, etc.) must be paid. This limited time approach may not meet the approval of games purists, but like one day cricket, it is not the real thing but is often more fun! This games timer is a fairly up-market type which has a two digit led display. This counts downwards at a suitable rate, and a buzzer is activated if a count of '00' is reached.

The circuit is based on a two digit down counter which has IC3 and IC4 to provide the counter, seven segment decoder, and display driver functions. The 40110BE also includes latches on the decoder outputs, but in this circuit these are set to the transparent mode by taking the latch enable input low, and they play no active role. Similarly, the unit counts continuously, and so the clock gating facility is not required. Accordingly, the toggle enable inputs are simply tied to the zero volt rail. SW1 is the reset switch, and it pulls the appropriate terminals of the counter chips high when it is activated. The 40110BE has the unusual feature of up and down clock inputs, plus carry and borrow outputs to drive subsequent counter stages. In this case it is a down counting action that is required , and it is therefore the down inputs and borrow outputs that are utilized. The up inputs are tied to the zero volt supply rail to avoid spurious operations.

The clock signal is provided by IC5 which is a low power 555 timer used in the normal astable mode. With the specified values this gives a clock frequency of approximately 1Hz, giving a readout in seconds. If optimum accuracy is required, R19 should be replaced with a 2M2 preset which can then be used to set a count rate of exactly one per second. Alternatively, you can simply settle for arbitrary scaling and use a value for R19 that gives a suitable total countdown time for the particular game being played. The clock frequency is inversely proportional to the value of R19 (eg halving R19's value doubles the clock rate). A little experimentation should soon pinpoint the best value.

IC2 is a dual D type flip/flop, but in this circuit IC2b is used as a divide by two stage, and IC2a acts as a latch. The purpose of these stages is to provide an output that latches in the high state when the counter is allowed to count right down to zero. This signal is used to operate a simple beeper circuit that provides an audible warning that the unit had cycled through a zero count. The beeper function is provided by a second low power 555 astable (IC1) driving a ceramic resonator (LS1). Note that LS1 must be a ceramic resonator such as the PB2720 and not an ordinary moving coil loudspeaker. In this application high volume is not necessary or particularly desirable, and LS1 can be an uncased resonator glued to the interior of the case behind a simple grille of holes. Both halves of IC2 have their reset input controlled by SW1, and the beeper is silenced when SW1 is activated.

When building the unit remember that IC2, IC3 and IC4 are CMOS types, and that the standard anti-static handling precautions should be observed when dealing with them. The current consumption of the unit averages out at about 50mA. A fairly high capacity such as four HP7 cells in a plastic holder are suitable as the power source.

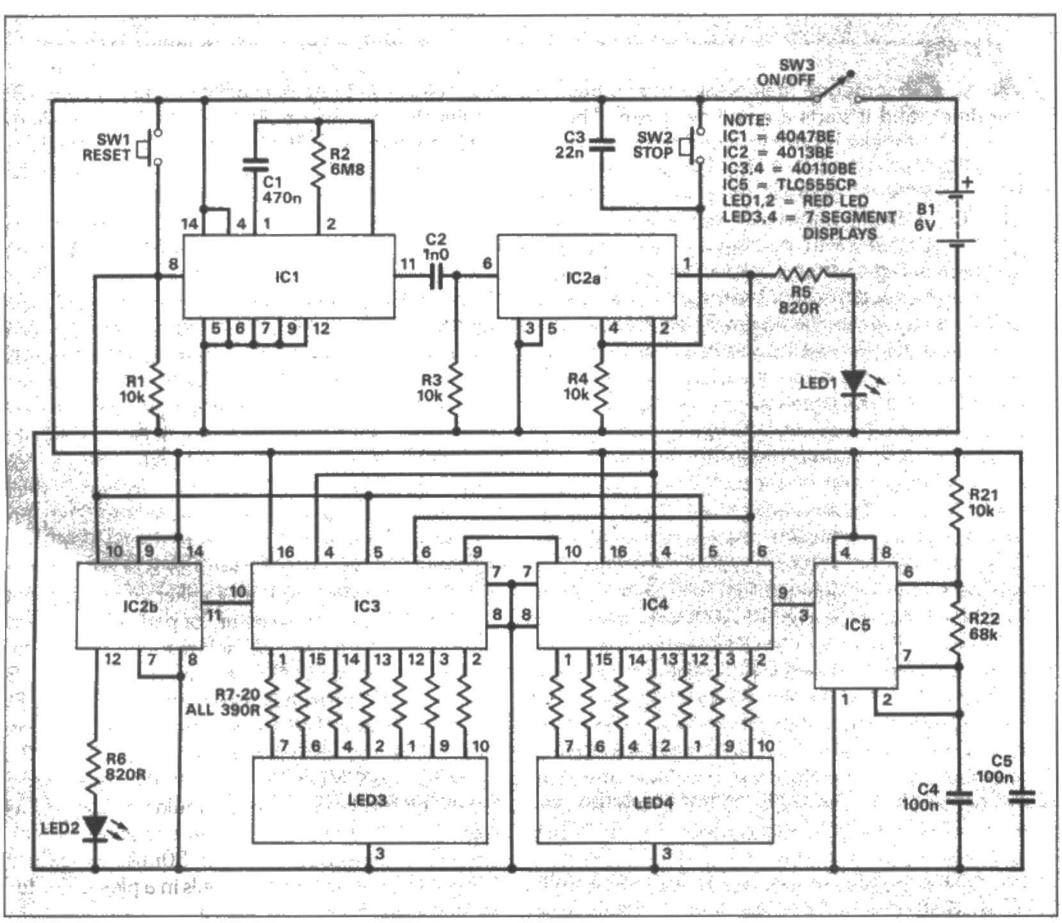
REACTION TESTER

While not exactly the most recent of ideas in the world of electronic amusements, a reaction tester remains a compulsive toy for anyone who encounters such a unit. Why it is that everyone seems ti be certain that their reactions are that bit faster than everyone elses, and they are always eager to prove it? Some people's reactions are certainly faster than others, but it is surprising how little difference there is in the reaction times of an average group of people. It is also surprising how much effect even quite small amounts of alcohol can lengthen reaction times (something that most constructors of this unit will presumably investigate very thoroughly!). This reaction tester is in the form of a simple timer having a two digit display. The display reads from 0 to .99 seconds, but it does not provide highly accurate results unless a suitable oscilloscope ot frequency meter is available, so that the clock frequency can be accurately set up. Even without any calibration the unit is still perfectly usable for amusement purposes, where it is relative scores that are of primary interest.

The circuit is based on a simple two digit counter. This has IC3 and IC4 to provide the counter, seven segment decoder, and driver functions. The displays must be common cathode led types, and the pin numbering in the circuit diagram assumes that standard 0.5 or 0.56 inch displays are used. The clock signal is provided by IC5, which is a standard 555 astable. It is connected direct to the clock input of IC4 since IC3 and IC4 have built-in circuits that can be used to gate the clock signal on and off. The specified values give oscillation at approximately 100Hz. If suitable frequency measuring test gear is available, replace R22 with a 39k fixed resistor and a 47k preset wired in series. The preset is then adjusted for a clock frequency of precisely 100Hz at pin 3 of IC5. The circuit uses a low power 555 for IC5 in order to minimise the battery drain, but an ordinary 555 should work just as well.

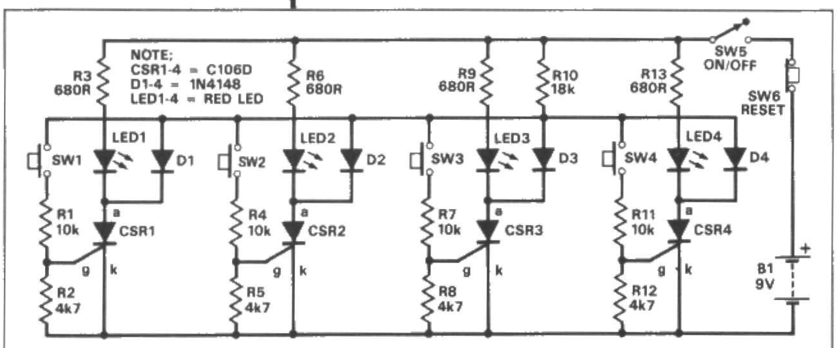
If the display should cycle right back to zero and go into a second count, this will be detected by IC2b. This is one section of a D type flip/flop. It is connected here to act as a simple latch, and it switches on LED 4 if an overflow occurs. Operating SW1 resets the circuit, with the counter going to zero and (when appropriate) IC2b is reset. A secondary function of SW1 is to start a new timing session. When activated it triggers IC1, which is a 4047BE astable/monostable. It is connected here to act as a positive triggered monostable having an output pulse duration of just under 8s. At the end of the pulse, C2 couples the positive going signal from the $\overline{Q}$ output of IC1 to the set input of D type flip/flop, IC2a. This gates the clock signal on, and switches on LED3 to indicate to the competitor that the timer has started. The competitor then has to press SW2 as quickly as possible in order to reset IC2a, stop the counter, and produce the lowest possible count. The frozen count is then displayed, and held until S1 is pressed again, when a new timing run commences.

The current consumption of the unit is largely dependent on the number of display segments that happen to be switched on at the time. It is typically about 75mA, and four HP7 size cells in a plastic holder should give a reasonable battery life. Connection to the holder is via an ordinary PP3 style battery clip. When constructing the unit bear in mind that all the integrated circuits are CMOS types, and that apart from IC5 (which has highly effective built-in protection circuits) they require the standard anti-static handling precautions to be observed.



QUIZ MONITOR

An essential part of any television style quiz game is an electronic unit to determine who was first on the button. Basically, all a unit of this type has to do is operate a separate indicator light from each contestant's push button switch, with all the other lights being frozen out once one of the lights has been activated. This avoids any arguments about who was first to press their button. A two button circuit of this type does not need to be particularly complex, and a form of flip/flop will do the job quite well. Units that have four or more push buttons can easily become quite complex if the circuit designer is not careful, with little prospect of being able to expand the system to cope with more switches if the need should arise. This circuit accommodates four push button switches, uses only a handful of inexpensive components, and is easily expanded to any desired number of push buttons.



The circuit is based on four thyristors, with each one being used as an electronic switch to control an indicator led. Operation of the circuit exploits the latching action of a thyristor. Unlike a transistor, once a thyristor is turned on it will remain in the 'on' state until the current flow through the device falls to a low level (usually a few milliamps at most). Cutting off the input current to the gate of a thyristor will not switch it off. In this circuit each thyristor has a push button switch and a bias circuit in its gate circuit. Operating one of these push button switches will result in the respective thyristor and led indicator being turned on.

The hold-off on other lights, once one of them has been activated, is provided by the four diodes (D1, D2, D3, and D4). The gate bias signal is obtained via R10, but once one of the thyristors has turned on there will be a path of conduction from the lower end of R10 to ground, through one of the diodes and whichever of the thyristors has been activated. This pulls the lower end of R10 down to a potential of only about one volt or so. The potential divider in each gate circuit then ensures that the gate current and voltage can not be sufficient to trigger any of the thyristors. This gives the required hold-off, but the latching action of a thyristor ensures that the one which has been activated will remain switched on. In order to reset the circuit SW6 is momentarily operated. This cuts off the power so that the current through the activated thyristor is reduced to zero, and it turns off.

The standby current of the unit is negligible, but it is still a good idea to include on/off switch SW5. This ensures that any accidental activation of the unit while it is not in use will not cause the battery to run down. The current consumption with the led activated is about 10mA. Large high brightness leds are probably the best type to use for this application. Although the unit is shown here as having four stages, it should work perfectly well with as few as two stages, or as many as a few dozen. In theory there is no upper limit to the number of stages that can be used in the circuit. The circuit relies on the thyristors having quite high sensitivities. Many thryristors require much higher gate trigger current than the maximum of 0.2mA required by the C106D. The use of substitutes is therefore not recommended.

ELECTRONIC DIE

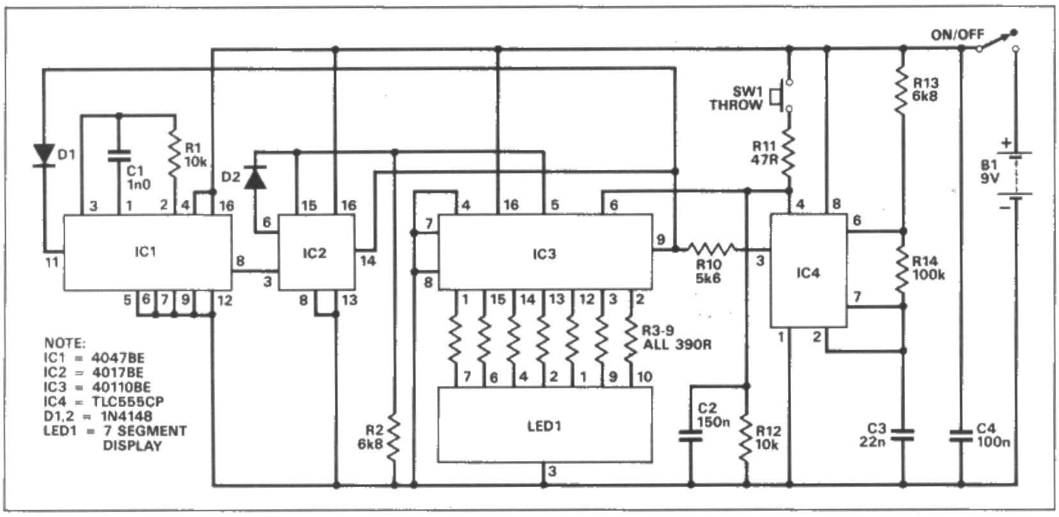
Electronic dice generally have either a seven segment led display, or use seven ordinary panel leds arranged in an 'H' pattern, with the appropriate led or leds being switched on to produce the required number patterns. For the sake of simplicity, I based this design on a seven segment led display. This enables the unit to be built around a standard counter, decoder, and display driver integrated circuit, but it leaves a few problems to be solved. Normal counter chips are designed to count from 0 to 9, whereas this application requires a count from 1 to 6. The counter must therefore be reset on the next clock pulse after a count of 6 is reached, which is not particularly difficult to achieve. It must be reset to 1 instead of 0, which is a bit more tricky.

This circuit is based on a CMOS 40110BE decade counter, seven segment decoder, latch, and display driver chip (IC3). The clock signal is provided by IC4 which is a low power 555 used in the standard astable mode. It is gated on and off via SW1. Operating this switch takes pin 4 of IC4 high and activates the oscillator. The counter then cycles through its 1 to 6 count sequence about one hundred times per second. This count is not visible on the display, not because it is too fast for the human eye to perceive what is happening, but because IC3 displays the previous count held in its latches until SW1 is released. The new final count is then fed to the latches and displayed. It is, of course, purely a matter of chance as to which number in the 1 to 6 range is displayed. The unit therefore gives a good die simulation, and no significant weighting problems were apparent when testing the prototype.

IC3 is used to reset the counter after it reaches a count of 6. This is a 4017BE decade counter and one of ten decoder. In this case the 7 output is coupled to the reset inputs of both IC2 and IC3 via D2. Both counters are therefore reset to zero as the 7 output of IC2 goes high. In order to eliminate the zero and move the unit on to a count of one, an extra clock pulse must be generated immediately after the counters have been reset. This is the purpose of IC1, which is a 4047BE connected to operate as a positive edge triggered monostable. It is triggered when the counters are reset, and the pulse it generates is crowbarred onto the clock signal so that it has the desired effect. R10 provides a loose coupling from IC4 to the counters so that this crowbarring does not involve any risk of exploding chips! D1 ensures that the clock signal is allowed to pass through to the counter circuits normally at other times.

When building the unit remember that IC1 to IC3 need the usual anti-static handling precautions. Apparently one or two inputs of the 4047BE lack protection circuits, and this component therefore needs more care than usual. The current consumption of the circuit is about 30-75mA, depending on the number of display segments that are switched on. It therefore requires a fairly high capacity battery, such as a PP9 size or six HP7 size cells in a plastic holder.

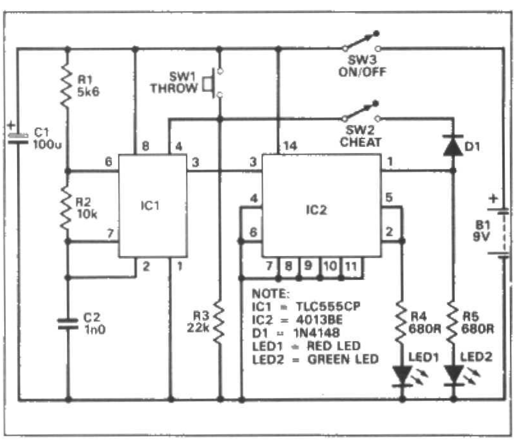
CIRCUITS



Note that the display must be a common cathode led type, and that the pin numbering in the circuit diagram assumes that it is a standard 0.5 or 0.56 inch type. A high brightness type is preferable, but not essential.

When the unit is initially switched on it might display any number, including 0, 7, and 9. However, once SW1 has been activated it should only display numbers in the range 1 to 6 thereafter.

HEADS OR TAILS



True randomness is one of those things that seems to be easily achieved using electronic means, but which is actually quite hard to produce. Having tried various random number generators and heads/tails circuits over the years, it is surprising how many of them are perfectly plausible in theory, but actually produce heavily weighted results in practice. There can be various causes of this, but it is often just a design flaw, with a minor oversight resulting in the circuit not being quite as even-handed as it might at first appear. Probably the biggest problem is that of stray coupling, particularly via the power lines. Normal levels of supply decoupling seem to be ineffective at preventing this problem. It can often be so severe that in reality the supposedly random generator produces the same result every time!

In my (fairly considerable) experience of random generator circuits the best route to true randomness, or something very close to it, is to keep the circuit as simple and straightforward as reasonably possible. The heads and tails circuit featured here simulates the tossing of a coin, and is based on one of the D type flip/flops in a CMOS 4013BE. This has its $\overline{Q}$ output connected back to its data input so that it provides a simple divide by two action. The second flip/flop is ignored, apart from some of its terminals which are wired to the 0V supply rail for static protection purposes. LED1 is the heads indicator led, and it is driven from the $\overline{Q}$ output of IC2. The tails led (LED2) is driven from the $\overline{Q}$ output. Consequently, only one or the other of the leds can be switched on at any one time.

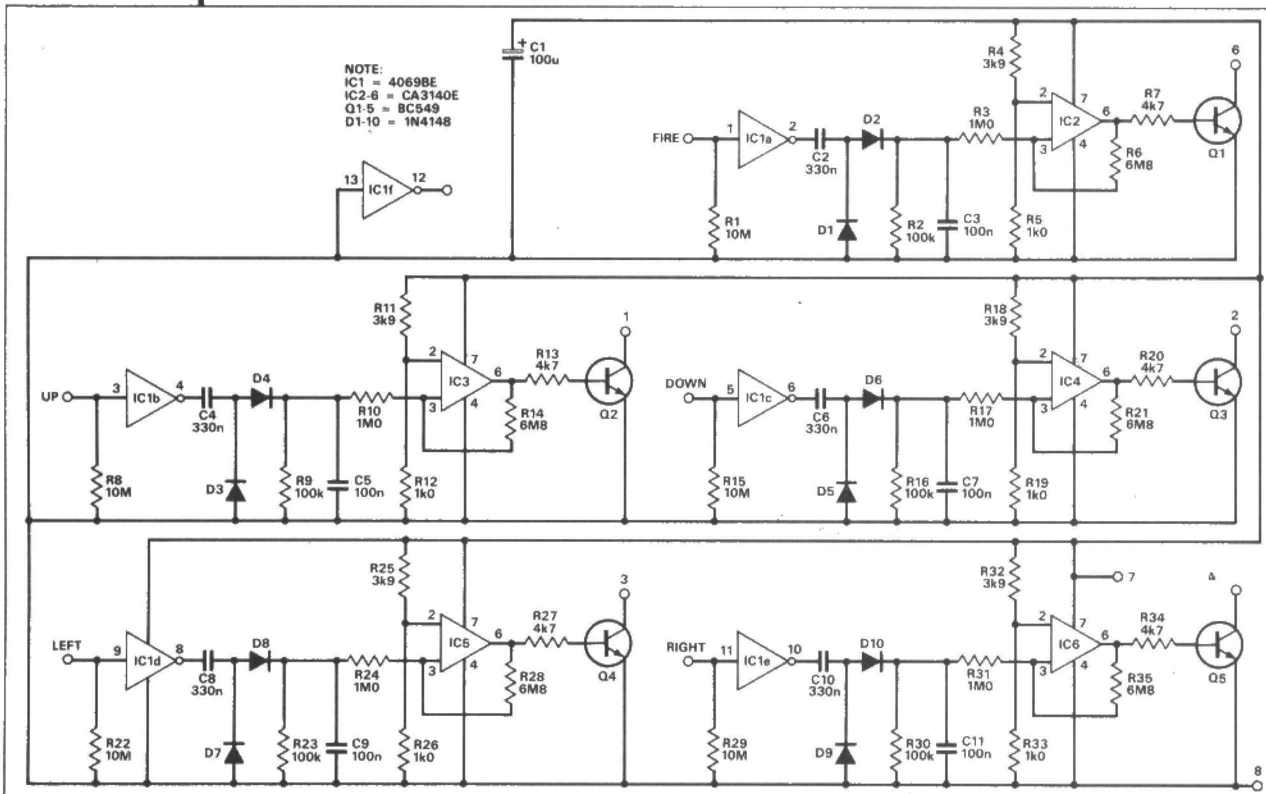
To toss the coin SW1 is briefly activated. While it is operated it takes pin 4 of IC1 high, and enables this 555 oscillator to run normally. When SW1 is released, pin 4 of IC1 is taken low by R3, and oscillation ceases. The operating frequency of IC1 is quite high at about 20kHz, and while it is oscillating the leds flash on and of at a rate which is far too fast for the human eye to perceive properly. It appears that both leds are switched on continuously but at about half normal brightness. Consequently, unless you are superhuman, there is no way of releasing SW1 when the desired led is switched on. It is purely a matter of chance whether it is the heads or tails led which is switched on (and remains on) when SW1 is released, giving the required randomness.

The circuit does not seem to suffer from any problems with feedback through the supply lines weighting results. In the original design there was a simple R-C timer circuit included at pin 4 of IC1, but this seemed to cause some very heavily weighted results. The more simple and direct approach used in the final design seems to give much better randomness. Do not be surprised if the unit sometimes provides the same result severaltimes in succession. This could easily happen when tossing a real coin. To test for true randomness you need to activate the unit about one thousand times, making a note of the results!

For those who would like a hi-tech practical joke, the unit has a built-in double-headed coin facility. If SW2 is closed the unit will function normally if a head is thrown. However, if the result is tails and pin 1 of IC2 is high, the coupling through D1 to pin 4 of IC1 keeps oscillation going for another cycle, when IC1 pin 1 goes low and oscillation is cut off. This effectively nudges the circuit from tails to heads, ensuring that the result is always heads. D1 prevents SW1 from pulling the Q output of IC2 high each time this switch is operated. It will be a bit obvious if SW2 is an ordinary switch. It should be some form of concealed switch, such as a tilt type mounted so that the double heads action is obtained only if the unit is held at a suitable angle.

The current consumption of the circuit is about 12mA, and any 9 volt battery should be suitable as the power source. The unit will also function with a 6 volt battery supply, but with slightly reduced led brightness.

TOUCH CONTROLLED JOYSTICK



Most home computers can be used with switch type joysticks of the standard Atari/Commodore variety. There are a few exceptions which use potentiometer type sticks (notably the BBC model B and IBM compatible machines), but most require the switch variety and have the standard 9 pin D connector with the standard method of connection. This kind of joystick consists of what is basically five s.p.s.t. switches. One of these is the firebutton, and it pulls the appropriate input of the joystick port low when it is activated. The other four switches also pull their respective inputs low when they are activated, and they are controlled via the stick. Setting the stick left, right, up, or down activates the corresponding switch. In practice it is possible to operate two adjacent switches at once, such as the up and right switches by setting the stick at the half past one position. This arrangement therefore enables eight different directions to be indicated to the computer.

The basic simplicity of a switch type joystick raises the possibility of alternative methods of control, including do-it-yourself versions. A few alternatives forms of joystick have been made available commercially from time to time, but do-it-yourself units seem to be something of a rarity. This design is unusual in that it is a stickless joystick! It is controlled via five touch contacts which are the fire button plus left, right, up, and down controls. Like a conventional switch type joystick, eight directions can be indicated. With this touch controlled version the intermediate directions are obtained by simultaneously activating the appropriate pair of adjacent contacts.

The unit is essentially five identical touch switches, with a separate circuit for each input of the joystick port. Each switch circuit has a CMOS buffer/inverter at the input. The purpose of this is to provide a very high input impedance. The input impedance of each switch circuit is set at 10M by an input bias resistor (R1 in the case of the firebutton switch for example).

Touching one of the input contacts results in mains hum picked up in the operator's body activating the buffer/inverter, producing a 50Hz squarewave signal at its output. This signal is rectified and smoothed to produce a positive d.c. signal. The time constant of the smoothing circuit is kept as short as possible so that the unit has a suitably rapid response time. The output from the smoothing circuit is fed to the input of a trigger circuit based on an operational amplifier.

Each switch has an open collector output stage. This is important, as the joystick inputs are sometimes used as part of the keyboard scanning circuit. Driving the joystick inputs from ordinary logic outputs can result in an apparent malfunction of the keyboard. Open collector outputs should totally avoid any problems of this type.

The unit is powered from the +5V supply available from the joystick port. Its current consumption is only about 10mA or so, and any computer should be able to supply this without difficulty. The pin numbering on the outputs is correct for a standard Atari/Commodore games port. The unit should be usable with any computer that has a +5V output on its joystick port, and is intended for operation with switch type sticks. The computer's manual should give connection details for the games port. Note that IC1 is a hex buffer/inverter, but that in this circuit only five sections of the device are actually utilized. The input of the sixth inverter is connected to the zero volt rail to provide static protection. All six integrated circuits have MOS input incidentally, and therefore require the standard anti-static handling precautions to be observed.

Try to arrange the touch contacts in a sensible arrangement so that the unit will be quick and easy to use. Use a plastic case so that there is no difficulty in keeping the contacts insulated from each other. Touch contacts can be obtained from some of the larger component retailers or large panel head screws make a good low cost alternative to the real thing.

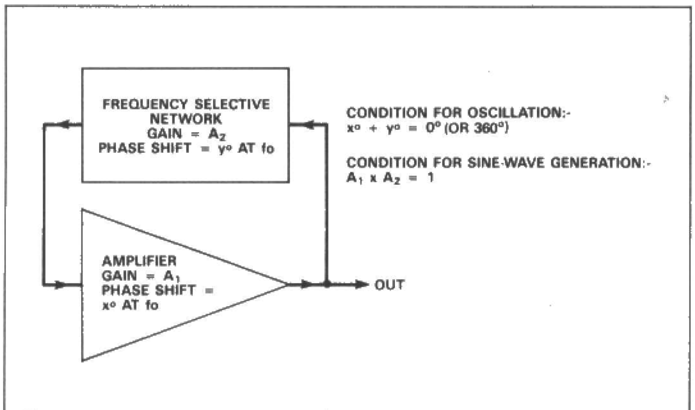


Fig. 1 Essential circuit and conditions needed for successful sine-wave generation

MAKING WAVES

Ray Marston presents the first of a two part selection of sine-wave generating circuits

The sine wave is the most fundamental and useful of all waveforms. There are various ways of putting together an oscillator to produce a sine wave output. The two basic passive component methods are the C-R combination and the L-C oscillator. However, sine wave outputs can also be synthesised via special waveform generator ICs. In this article we will look at each principle, in turn. This month we concentrate on the C-R principle.

C-R Oscillator Circuits

Two basic requirements must be fulfilled to produce a simple sine-wave oscillator, as shown in Fig. 1. First, the output of an amplifying device (A_1) must be fed back to its input via a frequency-selective network (A_2) in such a way that the sum of the amplifier and feedback-network phase-shifts equals zero (or 360° or a multiple of 360°) at the desired oscillation frequency, so that $x° + y° = 0°$ (or 360°). Thus, if a transistor amplifier gives 180° of phase shift between input and output, an additional 180° of phase shift must be introduced by a frequency- selective network connected between input and output to meet the first requirement of a sine-wave oscillator.

The second requirement for sine-wave oscillation is that the gain of the amplifying device must exactly counter the loss (attenuation) of the frequency-selective feedback network at the desired oscillation frequency, to give an overall system gain of precisely unity, so that $A_1 \times A_2 = 1$. If the system gain is less than unity the circuit will not oscillate, and if greater than unity the system will be over-driven and will produce distorted (non-sinusoidal) waveforms.

The frequency-selective feedback network used in a sine-wave oscillator usually consists of either a C-R (capacitor-resistor) or an L-C (inductor-capacitor) filter network. Figure 2 shows the practical circuit of one of the crudest members of the C-R sine-wave oscillator family, the so-called *phase-shift* oscillator.

Here the output (collector) signal of transistor amplifier Q1 is fed back to its input (base) via a three-stage C-R ladder network, essentially comprising C1-R1, C2-R2 and C3-R3. Each C-R stage of the ladder produces a phase shift between its input and output terminals. The size of the shift depends on frequency and component values, but has a maximum value of 90°.

The phase shift of the complete ladder network equals the sum of the shifts of each stage. In Fig. 2, where C1=C2=C3=C, and R1=R2=R3=R, the total shift equals 180° at a frequency of $\frac{1}{14CR}$. Since Q1 itself produces a shift of 180° the circuit actually oscillates at that frequency. Note that the three-stage ladder network gives an attenuation factor of about 29 at the oscillation frequency so that a high-

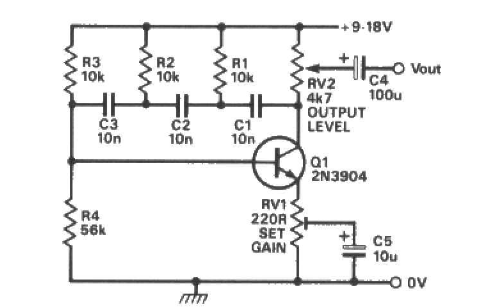


Fig. 2 800Hz phase-shift oscillator circuit

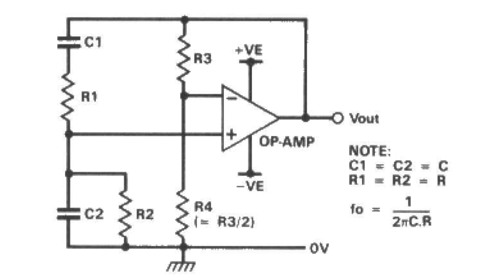


Fig. 3 Basic Wien bridge sine-wave oscillator

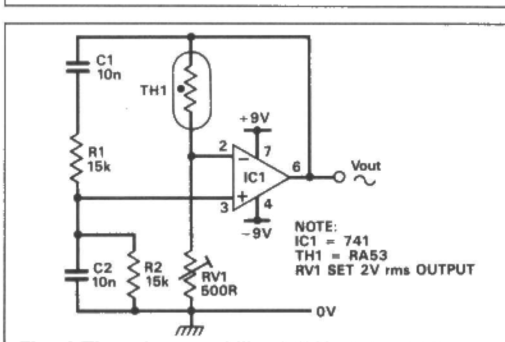


Fig. 4 Thermistor-stabilised 1kHz Wien bridge oscillator

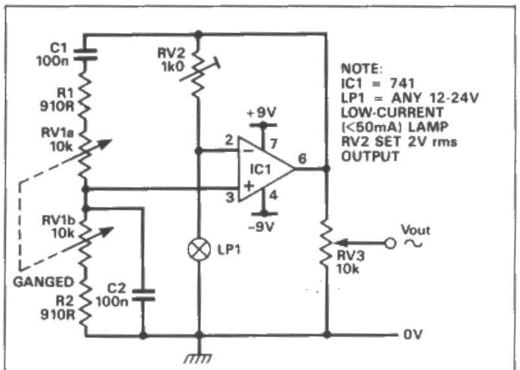


Fig. 5 150Hz-1.5kHz lamp-stabilised Wien bridge oscillator

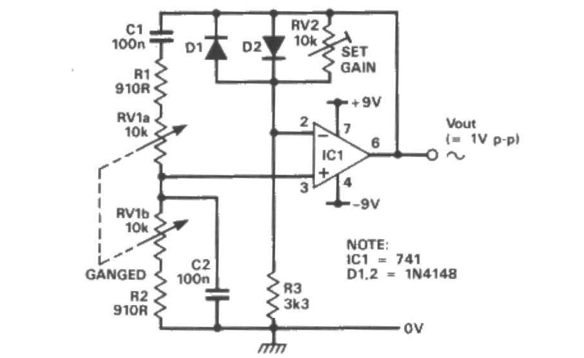


Fig. 6 Diode-regulated 150Hz-1.5Hz Wien bridge oscillator

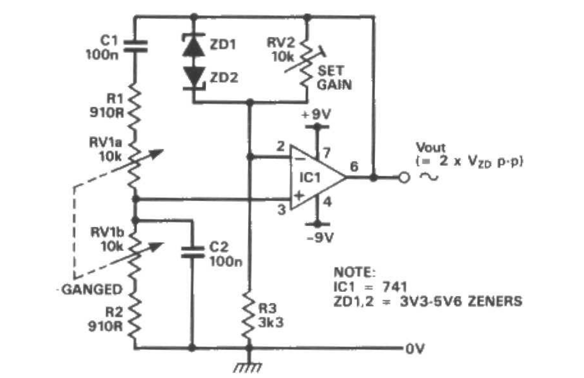


Fig. 7 Zener-regulated 150Hz-1.5kHz Wien bridge oscillator

gain transistor must be used for Q1 to compensate for this loss.

In use, the circuit can be set up by carefully adjusting RV1 until the circuit just goes into oscillation, thus producing a reasonably pure sine-wave output. In practice, oscillators of this type need frequent re-adjustment if good sine-wave purity is to be maintained, since the circuit has no inherent gain stability. Such circuits are useful, however, as simple fixed-value low-frequency sine-wave generators.

One of the best and easiest ways of making an R-C based sine-wave oscillator is to connect a standard op-amp and a frequency-selective Wien Bridge R-C network as shown in Fig. 3. Here, the frequency-sensitive Wien network is constructed from R1-C1 and R1-C21, normally with symmetrical components as noted on the diagram. The main feature of the Wien network is that the phase relationship of its output input signals varies from $-90°$ to $+90°$, and is precisely zero at a centre frequency of $1/2\pi CR$, or $\frac{1}{6.28CR}$. At this centre frequency the network has a voltage gain of $\times 0.33$.

Thus the Wien network is connected between the output and the non-inverting input of the op-amp, so that the circuit gives zero overall phase shift at fθ and the actual amplifier is given a voltage gain of $\times 3$ via feedback network R3-R4, for an overall gain of unity. The circuit thus provides the basic requirements for sine-wave oscillation. In practice, however, the ratios of R3-R4 must be carefully adjusted to give the overall voltage gain of precisely unity that is necessary for low-distortion sine-wave generation.

The above circuit can easily be modified to give automatic gain adjustment and amplitude stability by replacing the passive R3-R4 gain-determining network with an active gain-control network that is sensitive to the amplitude of the output signal, so that gain decreases as the mean output amplitude increases, and vice versa. Figures 4-8 show some practical versions of Wien Bridge oscillators with automatic amplitude stabilisation.

Thermistor Stabilisation

In the 1kHz fixed-frequency oscillator circuit of Fig. 4, the output amplitude is stabilised by an RA53 (or similar) negative-temperature-coefficient thermistor. TH1 and RV1 form a gain-determining feedback network.

The thermistor is heated by the mean power output of the op-amp, and at the desired output signal

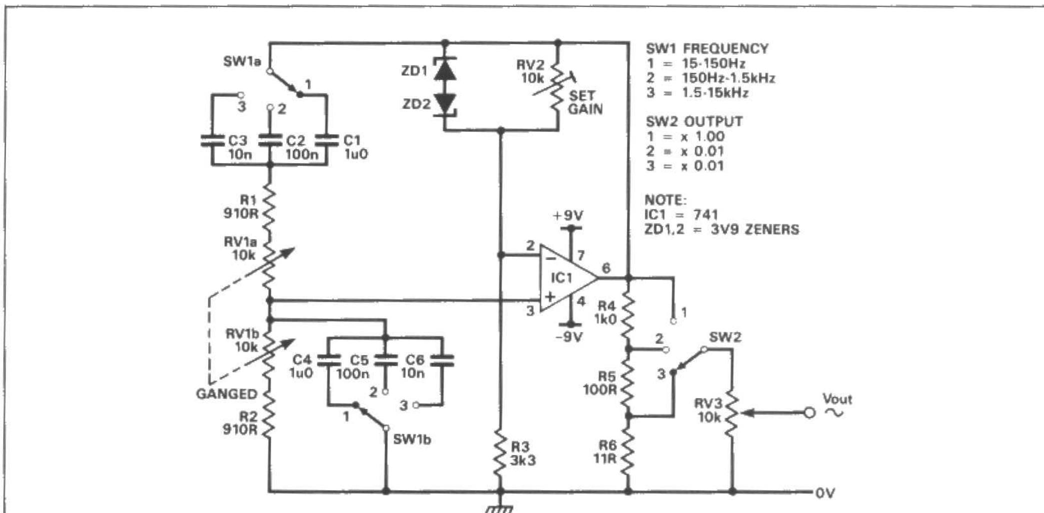


Fig. 8 Three-decade (15Hz-15kHz) Wien bridge oscillator

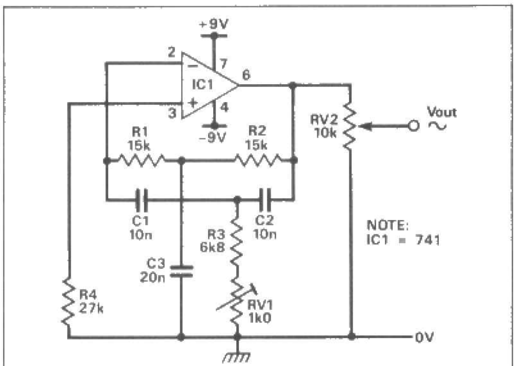


Fig. 9 1kHz Twin-T oscillator

level has a resistance value double that of RV1, giving the op-amp a gain of ×3 and the overall circuit a gain of unity. If the oscillator output amplitude starts to rise, TH1 heats up and reduces its resistance (or vice versa) thereby automatically reducing the gain of the circuit and stabilising the amplitude of the output signal.

An alternative method of thermistor stabilisation is shown in Fig. 5. In this case a low-current lamp is used as a positive-temperature-coefficient thermistor, and is placed in the lower part of the gain-determining feedback network. As the lamp heats up, its resistance increases thereby reducing the circuit gain and providing automatic amplitude stabilisation. This circuit also shows how the Wien network can be modified by using a twin-gang pot to make the oscillator frequency variable over the range 150Hz to 1.5kHz, and how the sine-wave output amplitude can be made variable via RV3.

In Figs 4 and 5 the pre-set pot should be adjusted to set the maximum mean output level to about 2V rms. Under this condition the sine wave has a total harmonic distortion of about 0.1%. A slightly annoying feature of thermistor-stabilised circuits is that in variable-frequency applications, the output amplitude of the sine wave tends to judder or 'bounce' as the frequency control pot is swept up and down its range.

Diode Stabilisation

The amplitude 'bounce' problem of variable-frequency circuits can be minimised as in Figs 6 or 7, which rely on the onset of diode or zener conduction for automatic gain control. In essence, RV2 is set so that the circuit gain is slightly greater than unity when the output is close to zero, causing the circuit to oscillate. However as each half-cycle nears the desired peak value one or other of the diodes starts to conduct and thus reduces the circuit gain, automatically stabilising the peak amplitude of the output signal. This 'limiting' technique typically results in the generation of 1% to 2% distortion on the sine wave output.

The maximum peak-to-peak output of each circuit is roughly double the breakdown voltage of its diode regulator element. In the Fig. 6, the diodes start to conduct at about 500mV, so the circuit gives a peak-to-peak output of about 1V. In Fig. 7 zener diodes ZD1 and ZD2 are connected back-to-back and may have values as high as 5V6, giving a peak-to-peak output of about 12V. Each circuit is set up by adjusting RV2 to the maximum value (minimum distortion) at which oscillation is maintained across the frequency band.

The frequency ranges of the above circuits can be changed via the C1 and C2 values (increasing them by a decade reduces the frequency values by a decade).

Figure 8 shows a variable-frequency Wien oscillator that covers the range 15HZ to 15kHz in three switched decade ranges. The circuit uses zener diode amplitude stabilisation and its output is adjustable via both switched and fully variable attenuators. Note that

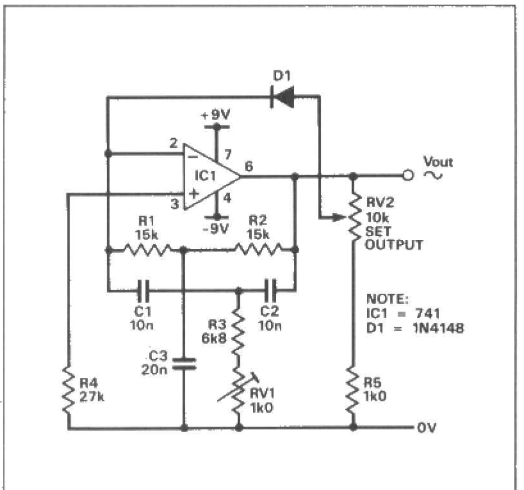


Fig. 10 Diode-regulated 1kHz twin-T oscillator

the maximum useful operating frequency of this type of circuit is restricted by the slew rate limitations of the op-amp. The limit is about 25kHz with a 741 op-amp or about 70kHz with a CA3140.

Twin-T Oscillators

Another way of making a sine wave oscillator is to wire a twin-T network between the output and input of an inverting op-amp, as shown in Fig. 9. The twin-T network comprises R1-R2-C3 and C1-C2-R3-RV1, and in a balanced circuit these components are in the ratios R1=R2=2(R3+RV1), and C1=C2=C3/2.

When the network is perfectly balanced it acts as a frequency – dependent attenuator that gives zero output at a centre frequency $f\theta$ of $\frac{1}{2\pi R1C1}$ and a finite output at all other frequencies. When the network is imperfectly balanced it gives a minimal but finite output at $f\theta$ and the phase of this output depends on the direction of the imbalance. If the imbalance is caused by R3+RV1 being low in value, the output phase is inverted relative to the input.

Here the twin-T network is wired between the output and the inverting input of the op-amp, and RV1 is critically adjusted so that the twin-T gives a small phase-inverted output at an $f\theta$ of 1kHz. Zero overall phase inversion thus occurs around the feedback loop, and the circuit oscillates at a centre frequency of 1kHz. In practice, RV1 is adjusted so that oscillation is barely sustained, and under this condition the sine-wave output has less than 1% distortion. Automatic amplitude control occurs because of the progressive non-linearity of the op-amp as the output signal approaches clipping level. The output is fully variable from zero to about 5V rms via RV2.

Finally, to complete this look at C-R oscillators, Figure 10 shows a method of twin-T amplitude control that gives slightly less distortion. Here, D1 provides a feedback signal via potential divider RV2. This diode progressively conducts and reduces the circuit gain when the diode forward voltage exceeds 500mV.

To set up the circuit, first set the RV2 slider to the op-amp output and adjust RV1 so that oscillation is just sustained. Under this condition the output signal has an amplitude of about 500mV peak-to-peak. RV2 then enables the output signal to be varied between 170mV and 3V rms.

Note that these twin-T circuits make good fixed frequency oscillators, but are not recommended for variable-frequency use, due to the difficulties of simultaneously varying three or four network components.

Next month we will look at L-C oscillator and sine-wave synthesiser circuits.

ETI

SAFETY FIRST

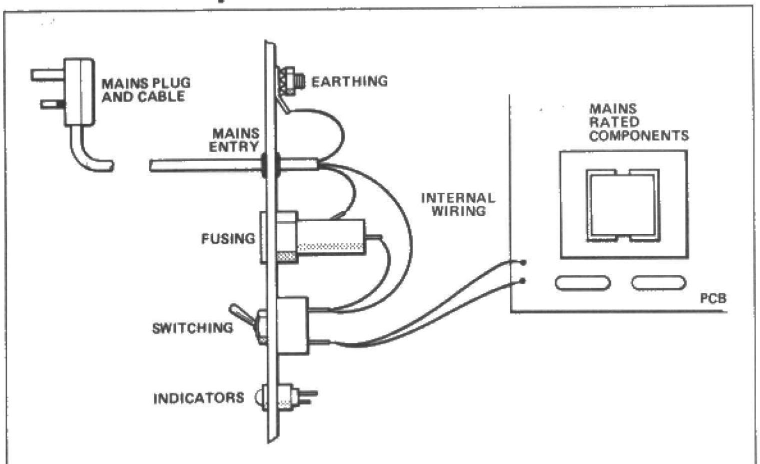


Fig. 1 The main danger areas to examine in electrical equipment

Andrew R Gayne is shocked by the amount of amateur and professional gear that ignores basic safety rules. Here he tells how to keep your power in place

SAFETY

The domestic mains supply is a fairly dangerous beast, yet becase it is taken for granted, it is often the least considered part of a project's design. Manufacturers and hobbyists alike can be guilty of failing to observe safe constructional practices, mainly through not being aware of the relatively straightforward design rules which apply.

For instance, a surprisingly common place for error is in the wiring of a standard household mains plug. When stripping a three core cable it is all too easy to leave the three conductors the same length — many manufacturers do so when supplying equipment with pre-tinned tails. If this is then wired into a standard layout plug and the cable then accidentally pulled, the conductor that will come under strain first will be the earth (a fibre-type or poorly fitted strain relief will give little protection if the cable is, for example, tripped upon). The earth could become detached within the plug, protection lost, and if the earth wire touches the live pin . . .!

This example demonstrates the essence of electrical safety precautions — predicting how each part could fail or be misused, either accidentally or deliberately, and ensuring that the resultant failure will be 'fail safe'. In the example described, the three conductors should be stripped to such a length that the earth will be the last to detach if the cable is pulled. Simple really, but so easy to overlook.

Figure 1 shows a typical arrangement for a hobbyist project, each of the areas identified being a possible source of problems. We shall take each in turn, to see where improvements can be made.

● *Mains plug.* Unless you buy your plugs from 'Honest Joe' in the local market, all BS1363 plugs are now fitted with sleeved pins for live and neutral, which prevent the pins from being touched when the plug is partially inserted. This type of plug should be considered an essential part of household safety (especially if there are children around). Any of the older unsleeved types should be consigned to the dustbin (go on, have a purge and do the whole house).

● *Mains cable.* There are only two current ratings of mains cable that will be of interest to the home constructor (unless you are into DIY storage heaters of course). These are 3A (0.5 sq mm) and 6A (0.75 sq mm). Use PVC-covered 3-core cable of an appropriate size for your project, keeping length to 1.5m maximum, the typical length required to get from a high level wall socket to the floor.

If an IEC type mains socket is being used, always make up the mains lead using 6A cable, the maximum rating of the socket itself. Your project may only require 3A cable, but there is no guarantee that a detachable mains lead will not be 'borrowed' to power up something else. Fusing of the mains plug should suit the cable (so 3A or 5A), your project itself being protected by an internally wired fuse of a suitable rating for the mains circuitry.

● *Mains entry.* To get mains into your project, either a plug and socket or a direct entry method can be used. Plug and socket is by far the safest, as long as a correctly rated type is used. The IEC type is the most common, similar in style to that found on the majority of domestic kettles. Beware of other types of 3-pin polarised connectors. Many are 240V rated but are intended for use inside equipment, where the use of a tool is required to access them. The general rule is that if you can *see* the conductor inside the socket (always the cable mounted half for mains input) then do not use it!

Direct cable entry methods for mains input are more commonplace than plug and sockets in home-built projects but have a greater tendency to suffer from poor assembly practices. The three essential features of direct cable entry are some method of preventing the cable from chaffing, anchorage to prevent the cable from twisting, and to use correct tail lengths. A snugly fitting grommet will prevent chaffing. Anchorage will have to be provided by a 'P' clip or similar internal clamp, because a cable that can freely rotate is likely to end up with broken or detached conductors. Strain relief bushes are available to perform both these functions, being a two part plastic clamp which fits into a square edged hole. Whatever method is used, your project should be subjected to some hefty pulling and twisting of the mains lead to prove the anchorage is secure. Correct tail lengths are required for the same reason as in the mains plug, and should the strain relief fail, the earth must be the last conductor to detach.

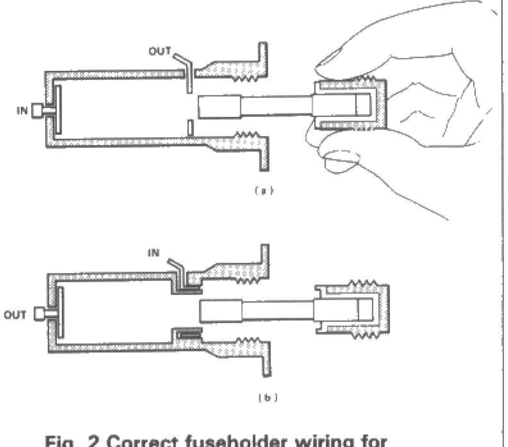


Fig. 2 Correct fuseholder wiring for
(a) holders with no internal sleeve
(b) sleeved holders

If it is required to supply mains to another unit via the main unit, then a shuttered outlet socket must be used. Direct connection via a permanently attached cable is poor practice in most situations. Suitable IEC types are available for this purpose.

- *The fuse.* All home built projects (and the majority of professional equipment) must be fitted with a fuse separate from that in the mains plug. It is unlikely that a 1in fuse with a suitable rating for the mains circuitry could be found — also an 'unauthorised' person may be tempted to throw any old fuse into the mains plug to get the unit going, but would be less likely to tamper with the unit itself.

The fuse holder should be externally accessible, but only releasable by the use of a tool. Finger releasable holders are a tempting fiddle for the young. Internal PCB-mounted spring clip types are not really suitable for home projects, because protective boots (fuse covers that is) and an unerring discipline to remove the mains plug from the wall would be required to use them safely. The rectangular, parallel entry type of fuse holder should not be used for mains, unless it forms part of a panel mounted IEC plug assembly, where the mains lead must be removed before the fuse can be accessed.

Safe wiring of the fuse holder must take into account the fact that mains could still be present, and will differ depending on the type of the fuse holder fitted. Older style fuse holders with two exposed internal contacts must have *live in* on the rear contact and *live out* on the side contact as in Fig. 2a. If it had been wired the other way round, the situation shown would be very dangerous if the fuse were good and the mains had been left on.

The most recent development in fuse holders is the shrouded type, where an internal plastic sleeve makes touching the side contact virtually impossible, see Fig. 2b. Where this type is used, live should be brought in on the side contact and taken out of the rear, the opposite to the older type. Never simultaneously fuse live and neutral, there is no need for it and if the neutral fuse blows the entire mains circuitry would remain live.

The fuse fitted should be of the sand filled ceramic cartridge type, which are preferred for their high breaking capacity (usually termed HBC fuses, previously known as high rupture capacity or HRC). Under extreme fault conditions a clear glass fuse can actually shatter, so their use on mains is to be avoided.

- *The switch.* Any equipment not intended to be permanently connected to the mains must be fitted with a mains on/off switch. For home projects it is good practice to fit a double-pole switch, to switch live and neutral together, as you are likely to poke around inside the unit whilst fault finding and so on. The practice of switching mains on one pole of a switch and the isolated low voltage on another is definitely bad practice.

If possible, mount the switch on the rear panel close to the rest of the mains circuitry, the convenience of a front panel mounted switch is countered by unnecessarily routing mains wiring to places where it would otherwise not go, increasing the number of potential failure points.

The question of which comes first, the switch or the fuse, is one that can cause great debates. It can be argued that the switch is a mains component, therefore it must be protected by the fuse. On the other hand, laziness (or inexperience) dictates that the unit might not be unplugged from the wall socket for a fuse change, except by the most safety conscious user.

Hence, if an unsleeved type fuse holder is used it may be safer to have the switch first. The answer to the question should therefore be determined by considering who the end user will be and the type of fuse holder used. Fuse first is the recommended method, as is the use of sleeved fuse holders.

- *Internal wiring.* Use the correct colours, be neat and tidy, solder and sleeve *every* joint. This is the recipe for safe wiring. Push-on crimp connectors should not be used to terminiate wiring as they can work loose, so permanently attach every joint, soldering being the most reliable method even if a $\frac{1}{4}$in spade terminal is present. Sleeving is essential for all joints.

The mains section should have absolutely no touchable live parts, remember your fault finding with the power on is probably yet to come. Route mains wires in separate looms from any low voltage wires, and away from any components that may become hot — regulators, power transistors and so on. Secure looms using tie wraps or the like, and use grommets whenever internal metalwork is passed through.

- *Mains on PCB tracks.* Probably the most common place for errors to occur, even though the techniques for safe board layout are remarkably straightforward. Maintain a gap of no less than 3mm between each live, neutral and earth track — and a gap no less than 5mm between isolated low voltage and mains.

It is good practice to group mains circuitry into a separate area of the board, if only to make it easier to check the above distances. Also avoid running mains tracks close to mounting holes, as metal mounting pillars might get used. Include an earth

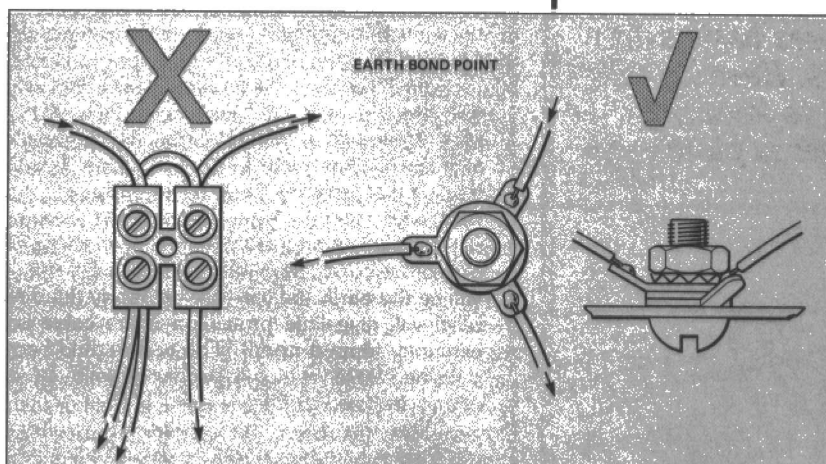


Fig. 3 Earthing effectively — a single bond point, not a chain

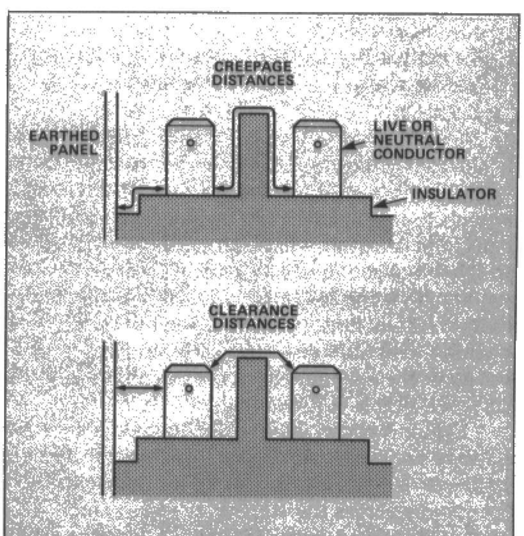


Fig. 4 Clearance and creepage

screen track between live/neutral and any low voltage circuitry wherever possible, to ensure that any flash over failure goes to earth and not the end user.

● *Indicators.* A bit of a 'catch 22' this one, because an indicator operating directly from the mains (such as a neon), should really be on all the time that mains is present in the unit, whether the unit is switched on or not. As most people want an indicator to show when the unit is switched on (arguably the safest form of indicator), and LED powered from the low voltage proves to be the most acceptable method of providing this. It avoids unnecessarily running mains wires to the front panel. Consequently, the advantage of having a true mains indicator is lost, because the LED can go out due to component failure with the mains voltage still present. Ideally then, all units should have two indicators, one for mains and one for power. Omitting the mains indicator is common enough to be acceptable, except on equipment that is not fitted with a mains on/off switch.

● *Earthing.* It is highly unlikely that a home constructor could correctly double insulate a project, therefore an earth will always be required. This front line protection for the equipment user has to be provided in a specific manner, otherwise a simple fault can make the unit more dangerous than if it were not earthed at all.

The basis for earthing correctly is a single Earth Bond Point, to which all items requiring an earth are connected by a direct wire link (see Fig. 3). The incoming earth from the mains lead is also directly connected to the earth bond point, therefore there will be a maximum of two physical connections (potential failure points) between the incoming earth and any earthed component. A daisy chain would increase the number of connections and risk of failure. The failure of one connection early in such a chain would disconnect the earth from many components.

All conducting components that could become live in the event of failure of a mains component must be earthed, which includes metal back panels, internal mounting metalwork, transformer casings, and so on. Project cases made up from a number of separate metal panels should have each panel individually earthed, assembly screws cannot be guaranteed to provide earth continuity due to paint, and other such unpredictable insulators. All earthing connections should be permanently attached to a clean metal surface. If bolted they must be locked with a shakeproof washer — push-on spade connectors are not a reliable earth. The rating of the wire used for earth connections must be equal to or greater than that of the live and neutral wiring. In the event of a catastrophic failure, the earth must be the last wire to burn out!

● *Creepage and clearance.* An electric current will flow through almost anything if the voltage is high enough, the breakdown of an insulator normally being in the form of a spark which can cause fires. Transients on the domestic mains extending into kV are not uncommon (especially in industrialised areas), so the effect of high voltages must be taken into account by ensuring minimum distances between live, neutral, and earth (the minimum distances described for PCB's form part of this requirement).

Figure 4 shows how clearance is the shortest distance between two conductors through air and creepage is the shortest distance between two conductors across the surface of an insulator. The latter is important because dust, coffee and other surface contaminants can reduce the effective resistance of the insulator. The minimum requirement for both is 3mm and must be complied with throughout the entire mains circuit.

Normally creepage will be found to be equal to or greater than clearance, although one regularly overlooked exception is the PCB-mounted connector. A connector with a 0.2in pitch will have a clearance distance of around 5mm but the pad size required on the PCB will make the creepage distance on the solder side of the board less than 3mm, unless adjacent segments of the circular pads are removed as in Fig. 5.

Check all components in the mains circuit after assembly, individual components may be OK, but once mounted the creepage and clearance between mains conductors on adjacent components and to earthed metalwork is of equal importance. This is a criteria where 240V rating does not necessarily imply mains rating. For example some toggle switches are 240V rated but have a very small clearance distance between poles, so they are not suited to switching live and neutral together.

● *Mains-rated components.* All components connected to the mains must be mains-rated, which is not necessarily the same as being 240V rated, as seen previously for switches. A good example of confused ratings is the suppression capacitor, normally connected in a delta arrangement between live, neutral and earth. Capacitors with a rating of 300V AC would appear to be suitable but recall the mains transients mentioned earlier. The odd kV across a capacitor of this rating even for just a few milliseconds would do it no good at all — exploding capacitors or even fire could result. For this reason there exists mains rated capacitors, termed class X (live to neutral) and class Y (live or neutral to earth), which are self-healing following transient fault conditions.

Fluctuations in supply voltage should also be taken into account, all equipment being able to operate from a continuous supply voltage of 240V ±10%. Cheap continental transformers with a 220V rating may sound 'near enough' but when run off 264V for a short while overheating can become a serious problem.

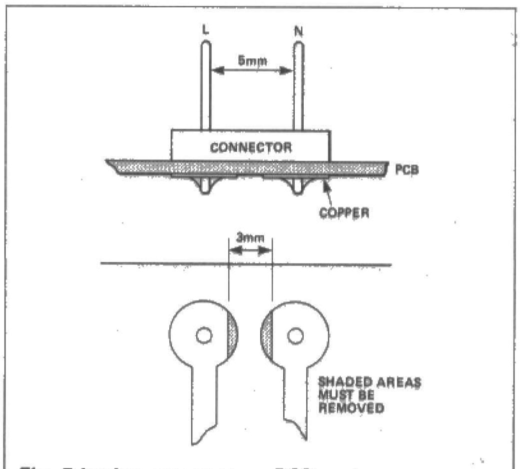


Fig. 5 Losing creepage on PCB pads

Fig. 6 International safety symbols

The suitability of the case for housing a mains-powered project must also be ascertained. Two-part plastic clip together types are not suitable, because if dropped they can fall apart. Ensure that access to the mains section requires the use of a tool and that panels which provide strain relief are strong enough not to flex when cables are pulled.

• *Labelling.* For home projects it is a good idea to provide a permanent reminder of the mains supply and fusing requirements of your project. For professional equipment it is an absolute necessity. The best method is an external label stating operating voltage, power consumption and type/rating of the fuse. The label should be permanently attached, so embossed tape is not really suitable. Use rub down transfers directly onto the rear panel, copiously laquered for protection.

Labelling of indicators is another common point of error because an indicator labelled 'mains' must operate directly from the mains to indicate when mains is present in the unit. If a low voltage or switched mains supply is used to provide the indication, then the indicator must be labelled 'power', 'on' — anything except 'mains'.

• *Standards and approvals.* Whilst all household mains plugs sold in British retail outlets must comply with BS1363, there is no absolute requirement for any other mains component to be similarly approved. It is therefore up to the buyer to determine whether the component is of suitable standard and quality.

The best indicators available to the home constructor are the approval marks of internationally recognised approval organisations. Most people are familiar with the British kite mark, which not only means that the item complies with a relevant standard (probably the best standards in the world, as Orson Welles might have said), but also that the entire manufacturing process has been approved. Finding the kite mark on individual mains components is sadly uncommon, however there are other European approval marks which (although generally based on supply voltages less than 240V) are a reasonable indication of suitability for use on British soil as long as the component is rated at 240V or greater. It is better for a component to have a European approval than to have no approval at all.

A list of common approval marks and the countries of origin are given in Fig. 6. USA and Canada have been included for reference purposes only, as they are based upon the North American 120V supply. Obviously components carrying these cannot be considered as suitable for 240V unless another European mark is present.

FURTHER READING

For those who like to curl up at night with a good read, here are a couple of relevant British Standards documents to keep you enthralled:

BS 415: 1979 (1987) Specification for safety requirements for mains operated electronic and related apparatus for household and similar general use. (phew!)

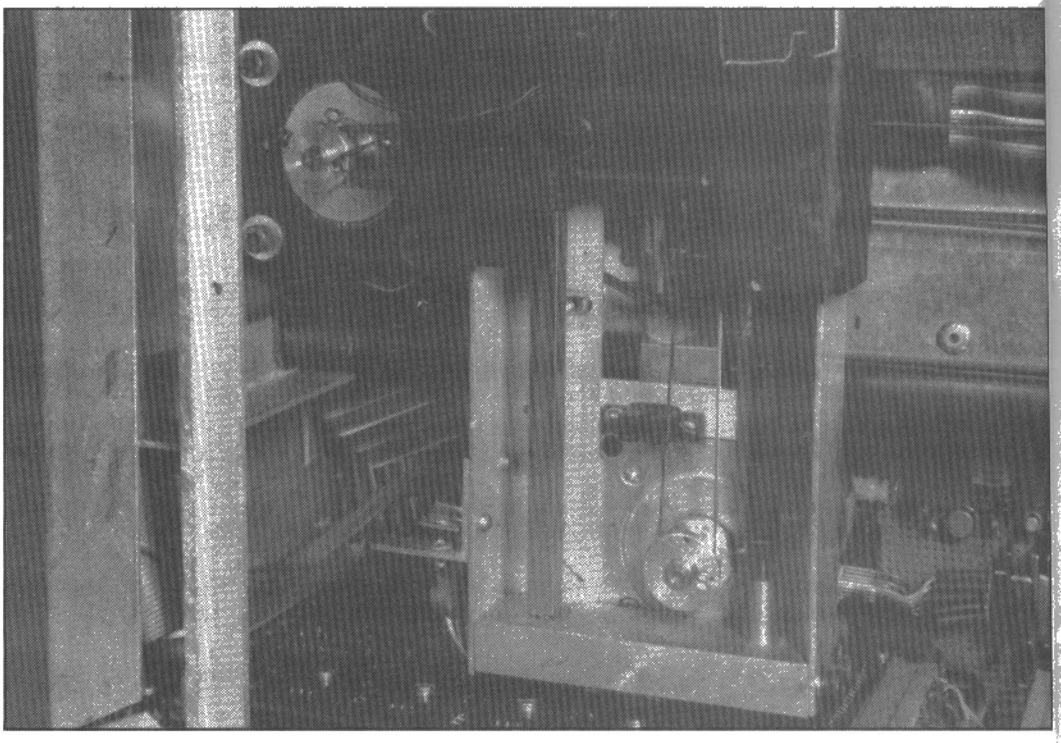
BS 3456: 1987 Specification for safety of household and similar electrical appliances – part 101: General requirements.

Any engineer involved in the design of mains operated equipment would be well advised to obtaion a copy of at least one of these, as they lay down the ground rules for all aspects of electrical safety as related to domestic equipment.

Armed with the data contained within this feature, the home constructor should be able to 'go forth and electrify' with a reasonable confidence that his project is safe. The information is by no means exhaustive, however, and situations will arise where common sense is the only guide. Remember — consider how it might fail, then ensure 'fail safe'.

ETI

TESTING TESTING



Mike Barwise moves our test gear series on to continuous graph displays — chart recorders and oscilloscopes

Until now we have looked at gear designed for examination of steady states — DC and very slowly changing signals. Continuous AC and discontinuous transient signals require a different set of tools. These include oscilloscopes, chart recorders, logic analysers, digitisers, spectrum analysers and their increasingly common computer-based derivatives.

All these measurement tools have one common characteristic in which they differ from the meters and probes we have discussed to date. This is that they use two operative parameters: the experimental measurand (your unknown voltage or whatever) and a defined constant for a given measurement (time for the oscilloscope or chart recorder, frequency for the spectrum analyser and so on). Thus, instead of delivering an instantaneous 'snapshot' of your experiment, these instruments show you how conditions are *changing* over a range of values of time, frequency or other characteristic. In other words, these instruments *draw graphs*.

Chart Recorders

The very simplest of this type of instrument is the needle chart recorder (Fig. 1). This consists of a very chunky analogue (moving coil) meter movement with a pen on the end of a needle. Instead of the conventional scale, there is a band of paper which is driven along beneath the pen by a constant-speed motor. In practice, the meter movement may be driven by a buffer amplifier to supply the power required to compensate for pen drag on the paper. In the absence of a signal to the meter, a straight line is drawn on the paper along its axis of movement. Signals to the meter cause the needle to deflect, describing arcs of varying displacement on the paper.

A purely mechanical version of this instrument is the *barograph*. This is used in museums and libraries to record changes in the air humidity and temperature (actually, this combined instrument should be called a thermo-humidigraph, but 'barograph' or air pressure recorder is generally accepted as shorthand). It is an ideal application, as neither the chart speed nor the pen speed are very high, and absolute accuracy and resolution requirement are relatively slack.

Improvements of this instrument use parallel pen movement and servo motors for positioning. Also, the pen carriage may move in both axes instead of the paper moving in one axis and the pen in the other. This opens the door to a minor improvement: instead of one axis being exclusively driven by a fixed speed motor, it may be supplied with a signal from a second

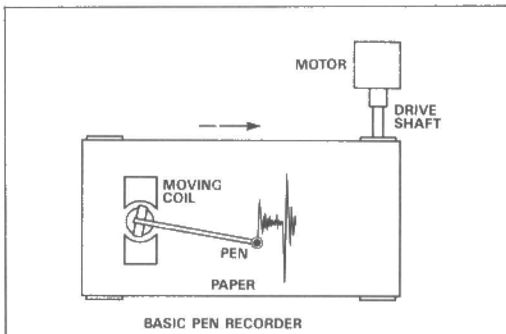


Fig. 1 The basic pen recorder

user defined source. The pen can now plot the relationship between any two changing quantities. The resulting instrument is then familiar to computer people as a *flat-bed plotter* (Fig. 2).

The flat bed plotter is characterised by reasonable resolution, generally good *repeatability* (the capacity to land in the same place more than once when the same input signals are present), and low drawing speed. These characteristics are fine for diagram drawing but the *limited system bandwidth* is unsuitable

TEST GEAR

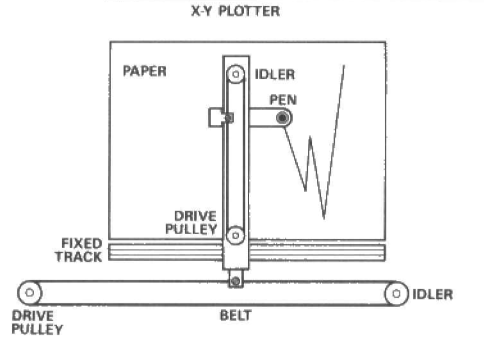
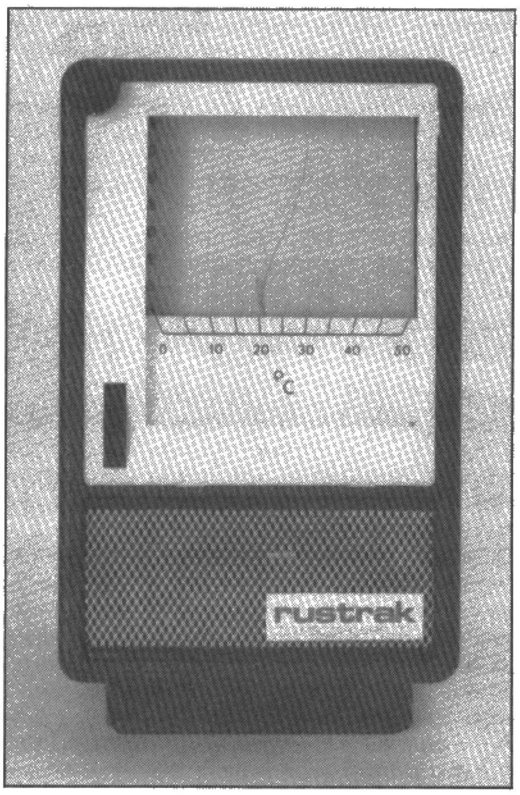


Fig. 2 X-Y plotter



for recording fast events in the real world. Obviously, the 2-axis *(X-Y co-ordinate)* approach is a good one, but we need something which responds faster.

The answer is the *cathode ray oscilloscope*.

Chart Recorders vs Oscilloscopes

Instead of a pen, the oscilloscope uses a beam of electrons which strike a fluorescent screen. This electron beam can be steered very fast indeed but it suffers from certain limitations. These are that the image on the screen does not last very long and fades away very soon after the electron beam has moved on (it has low *persistence*), plus the *linearity* and *resolution* of the electron tube image are quite low compared with the flat bed plotter.

The limitations of each system (flat bed plotter drawing speed, scope trace persistence, resolution and linearity) and advantages(flat bed plotter permanent paper record, scope high *writing speed*) suggest the best application of each instrument. The flat bed plotter is most useful for recording *fairly slow one-off events* where high resolution is required. The oscilloscope is best at displaying *repetitive fast waveforms* which the pen recorders cannot keep up with, though the penalty is lower resolution.

I guess the flat-bed plotter (which has a lot in common with your computer dot-matrix printer) is a fairly familiar tool. ETI published a design for an intelligent plotter back in Feb-Apr 89 and readers can refer there for further information. The oscilloscope is worthy of examining in more detail. It contains several additional features which make it about the most generally useful piece of test gear you can own.

Oscilloscopes

Figure 3 is a block diagram of the guts of a simple oscilloscope. The most basic sections are the *timebase generator* and the *Y-amplifier*. These control the horizontal and vertical displacement of the electron beam.

The timebase generator produces an extremely repeatable linear voltage ramp (Fig. 4). It is not left to free run (which would produce a continuous sawtooth wave), but is *triggered*. This means that it sits and does nothing until an input signal is supplied to it, when it generates a single ramp and then stops, waiting for another trigger (rather like most of us on Friday afternoon — it needs a nudge every time you want it to do something).

The voltage ramp it generates is supplied via various amplification and conditioning circuits to the electrodes beam (and thus the bright spot) move from left to right. The *distance* the spot lands from the left hand side of the screen is *directly proportional* to the voltage applied to the electrodes, so the linear ramp

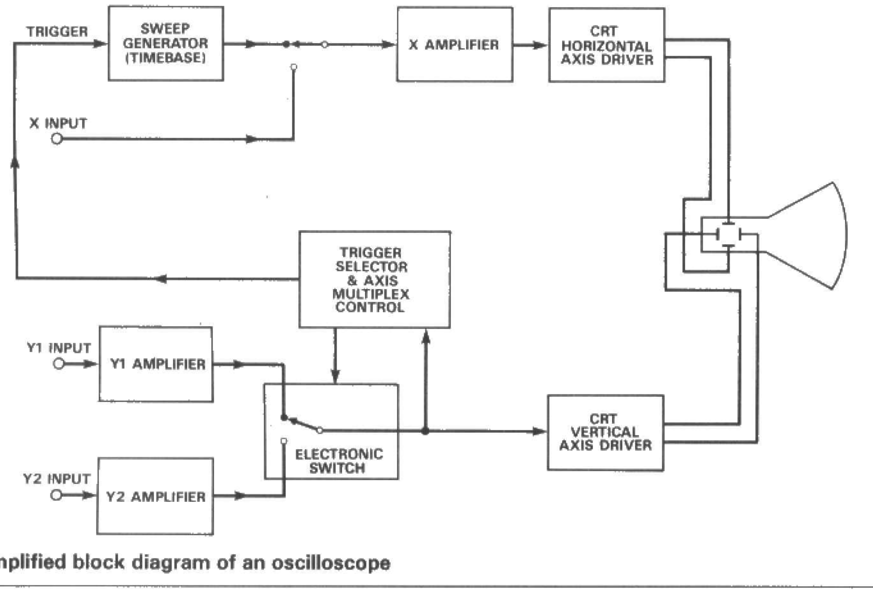


Fig. 3 Simplified block diagram of an oscilloscope

causes the spot to cross the screen *(sweep)* at a constant speed. However, it is essential that the start of the sweep is *synchronised* with the signal coming in to the vertical or Y input of the scope. This will become clear as we examine the Y-amplifier.

The Y-amplifier output causes a vertical deflection of the scope spot proportional to the voltage applied to its input. This signal may be *bipolar* (that is, a positive or negative voltage) so the vertical rest position of the scope spot is half way up the screen.

We can predict that in the absence of a Y input signal the scope spot will draw a horizontal line across the screen halfway up (provided trigger pulses are being applied to the input of the ramp generator). We can similarly predict that, in the absence of these trigger pulses, a varying signal applied to the Y-amplifier input will cause the spot to draw a vertical line at the left-hand edge of the screen.

Now let us consider a real signal applied to the *Y input* of the oscilloscope. A good choice would be the 50Hz mains frequency sinusoid obtained from the output of a small transformer (say 10V). Our basic scope needs a Y axis signal of ±5V to swing the spot between the top and bottom of the screen and the screen is divided into ten 1cm divisions: it has a *1V per cm vertical sensitivity*. It follows that the 50Hz 10V sinusoid will fill the vertical axis of the screen. With the timebase generator disabled, we get a vertical line the full height of the screen at its left-hand edge.

This is not very useful. We want to see the wave form of the signal. Indeed, we want to see one cycle of the 50Hz sinusoid on the screen. A simple calculation tells us that one cycle of 50Hz lasts 20ms. Just as an experiment, let's rig the timebase generator to be free-running (that is, not to require triggers but to generate a continuous sequence of voltage ramps). The resulting screen image is not at all what we want: it's a mess! The sinusoidal *trace* rolls constantly to the left of the screen — rather like the effect on your television if you fiddle with the vertical picture hold control (naughty!) only sideways instead of up and down. A single cycle of the 50Hz sinusoid is indeed displayed across the screen, but it starts at a constantly changing point on the waveform.

The problem lies in the difference between theory and practice. The sweep voltage ramp we showed in Fig. 4 rose from the base line to maximum voltage linearly and then returned *instantly* to the base line. The real system cannot do this. The electronics take a finite time to turn off the electron beam, return it to the left-hand edge of the screen and turn it on again. The total time between successive sweeps is more than 20ms. This means that the input sinusoid is drawn on the screen starting a little later on each sweep, resulting in the appearance of leftward roll. This problem is solved by the *triggering* of the timebase generator.

Suppose we trigger the timebase generator every time the Y signal crosses the zero volts line (centre of vertical scale). The first sweep will correctly draw the single cycle of the sinusoid we want on the screen. The next trigger will arrive *while we are returning to the left hand side of the screen* and will be ignored. The third trigger will cause a second sweep to be performed and so on. Every *alternate* trigger causes a valid sweep. We are thus only displaying one in every two Y signal cycles, but assuming the signal is constant in shape and amplitude, a stable trace will show on the screen — we have *locked* the scope to the Y signal.

This argument shows the importance of triggered sweep and also why the scope is best used to monitor *continuous* signals. I make no apology for the lengthy discussion, this is one of the most important points to remember when using the oscilloscope. There *must* be a regular signal to lock onto if you want a stable (readable) display. Later on (when we discuss measurement techniques) I will show you ways of creating a suitable locking signal where there is apparently nothing suitable already.

The real timebase generator has a range of

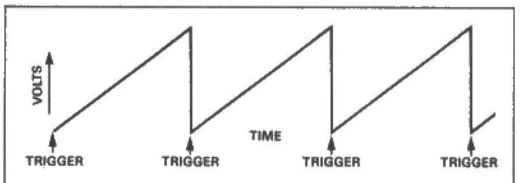


Fig. 4 The oscilloscope timebase or sweep generator output waveform

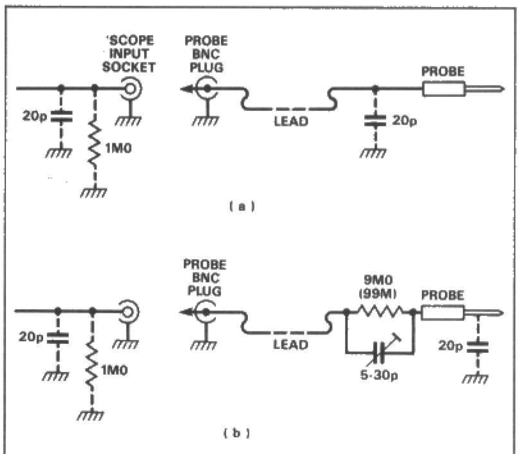


Fig. 5 (a) x1 scope probe (b) multiplier scope probe (x10 or x100)

switchable sweep speeds built in (and sometimes a continuously variable control as well), and can also frequently be switched out of circuit altogether, allowing an external signal *(X input)* to be substituted via a front panel socket. The source of triggers is normally selectable from

- the peak value of the incoming Y axis signal.
- a user-defined point on the Y axis signal (a user selected *threshold voltage*).
- a front panel socket for external trigger pulses.

The Y amplifier incorporates a range of switched *gains* (amplification factors) allowing signals with widely differing voltage swings to be displayed at maximal size on the screen.

So far we have discussed a theoretical basic oscilloscope. The real thing has several sophistications in addition.

The first is *dual trace* which allows two Y axis signals to be observed at once on the same screen. This is very useful when comparing, say, the input and output signals of an amplifier, or the clock and output of a logic circuit. Very very expensive oscilloscopes sometimes use a special picture tube with electron guns, allowing genuine simultaneous writing of two traces on the screen. This is, however, unnecessarily expensive for most purposes. The normal (affordable) techniques are *chopping* and *alternate* trace. Both techniques switch between the two Y input signals 'chopping' switches at a very high speed so that each trace consists of a row of bright dots within one sweep, and 'alternate' performing a complete sweep looking at the Y_1 signal and the next complete sweep looking at the Y_2 signal. Persistance of vision causes the eye to see two simultaneous complete traces (just as you cannot see the domestic TV picture being refreshed).

Chopping is normally used at very low sweep speeds, where the image of one trace would fade while the other was being written in alternate mode,

and alternate is used at high sweep speeds where the chopping might interfere with detail in the trace. A necessary addition to the scope circuity to allow dual-trace working is a means to move the horizontal position of each trace up and down the screen, so that the two traces can be displayed without overlap. This is performed by adding an *offset voltage* to the signal just before the last stage (the tube Y axis deflection amplifier), and is adjustable via a control on the front panel.

In a dual trace scope, internal triggering can normally be derived from either Y_1 or Y_2 at the push of a button. More sophisticated alternative triggers are also available: 50Hz mains triggering for use by TV engineers (locked to the TV frame rate); AC (capacitively coupled) trigger from Y input (ignores any DC offset when determining trigger voltage); low-pass and high-pass filtration to select desired trigger points out of complex signals.

The scope Y axis inputs can also be coupled direct (DC coupled), via capacitors (AC coupled) or grounded (to set reference levels on the screen).

The final sophistication common on good oscilloscopes is a *Y delay*. When a trigger is received by the timebase generator, it turns on the electron beam and starts a sweep. However (once again) this does not happen *instantly*. A short time elapses between the trigger and the start of a visible trace on the screen. Left to itself, the basic scope would always start too late.

The solution is the Y delay. A *delay line* (a circuit which makes the signal late for work without distorting it) is included between the output of the Y amplifier and the tube Y axis driver. The delay caused by this circuit is tuned to match the sweep delay of the X axis system, so that the signal which caused the trigger arrives at the tube Y deflection system just as the sweep starts instead of too early. Very sophisticated instruments frequently have an additional user adjustable delay which can be as much as 100ms, controlled from the front panel which allows the examination of signal detail which occurs long after the trigger event. More of this when we discuss applications.

Leads, Probes and Inputs

When we looked at meters, any old piece of wire of reasonable thickness would mostly do as a test lead. Its resistance shouldn't be significantly high, but that was about the only restriction.

Of course every piece of wire carrying a signal has series inductance (frequency dependent resistance) and parallel capacitance (frequency dependent leakage), but at very low frequencies from DC to 20kHz (audio band) these effects are so small for single straight wires as to be quite safely ignored.

This is not the case when we use the oscilloscope, as most often we are looking at signals in the frequency range of 50kHz to 150MHz. Therefore, test leads for scopes have to be much more carefully designed and are somewhat more complex than just bits of wire.

There are two main kinds of oscilloscope probe: *direct* or *×1* probes and *multiplier* — frequently *×10* or *×100* probes. The standard scope connector plug for both types is the 50R BNC bayonet type. Very occasionally, the 50R UHF type (similar to the CB radio antenna plug) is used on older equipment.

The first kind is the simplest. They consist of a screened lead with a BNC plug for the scope socket at one end and a very carefully designed low capacitance probe be at the other. Reference to Fig. 5a shows that there is still a small parallel self capacitance in the probe and this will limit the upper working frequency of the probe. The *loss* through this capacitance increases as the frequency rises. Assuming the standard oscilloscope input (a 1M *impedance* roughly resistance to ground), the probe will reduce (*attenuate*) the input signal by 50% at the frequency where the self capacitance has an impedance of 1M0.

In addition to this upper frequency limit, the ×1 probe input impedance of 1M0 is too low for safe testing of many small-signal circuits. This type of probe is fine for audio testing but can cause problems with modern radio and digital systems such as CMOS.

The basic multiplier probe (Fig. 5b) is a bit more complicated. The probe tip includes a *series resistor* which defines the multiplier. A 9M0 resistor gives us a ×10 probe (as the scope input resistance is 1M0 input impedance, and a 99M resistor gives us a ×100 probe with a 100M input impedance.

However, this type of probe goes one stage further. Just as the probe and scope input form a *resistive divider*, so it is possible to create a *capacitive divider* which will compensate for the parallel self capacitance of the probe. This is done by positioning the probe resistor as near as possible to the probe tip, and wiring a small capacitor across it (Fig. 5b). This capacitor forms a second *potential divider* which applies a trim to the system to compensate for high frequency losses. The upper frequency limit of the probe is thus greatly extended.

In practice, this probe-tip capacitor is a small *adjustable* component to allow it to be set to match scope sockets with differing parallel self capacitance. A *calibrator* output (a very clean high-frequency square wave is generally available at the front panel of any good scope for setting the probe trim up.

The most commonly encountered probe is a *switched probe*: It is usable as a ×1 or a ×10 by setting a small switch on the probe body. This is a good general purpose probe with the advantage of convenience, but it does not perform in either mode as well as a dedicated ×1 or ×10 probe. For critical work it should be avoided.

The final point in this resume of the oscilloscope and its probes is to note that special precautions must be taken if the scope is connected to an experiment via *plain screened leads* with BNC connectors at each end. A cable like this is designed to have a *characteristic impedance* of 50R. The experimental signal will tend to be *reflected* back down the cable when it hits the 1M0 impedance at the scope socket, severely messing up measurements, particularly at high frequencies. You are in essence adding a crude high frequency LC tuned circuit (an inductor and a capacitor in parallel) to the circuit under test.

If it is essential to use leads of this type (probably you have nothing else in the workshop 'cos somebody's nicked your probes), the answer is to put a *50R terminator* at the scope socket. In its simplest form, this consists of no more than a 50R resistor across the socket (centre pin to ground). A BNC 'T' piece can be used, with the lead coupled to one branch and the resistor soldered across a spare BNC plug. If you are rich, you can get 50R terminators ready made, either for use on a 'T' piece, or in tubular form with a plug one end and a socket the other for in-line connection. The one point to remember when using the BNC lead and terminator is that the scope will display the signal at *50% of its real amplitude* as the line impedance and the terminator resistor form equal value upper and lower halves of a potential divider.

That's about it for now. Next month we will look at *logic analysers*, *spectrum analysers* and ancillary measuring instruments such as *frequency meters* and *LCR bridges* before moving on to the various types of *signal generator*.

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COMING TO BLOWS

Mike Bedford reviews a trio of EPROM programmers for the PC

REVIEW

In view of ETI's recent emphasis on the IBM PC and the readership's enthusiastic reception of this theme, Stag's recent introduction of the Stratos EPROM programmer seemed an ideal opportunity to investigate the field of PC compatible programmers. This article takes the form of a review in which the Stratos and a couple of Far Eastern products are compared as development tools for the home user and small scale business applications.

Before getting down to the nitty gritty, however, it would be appropriate to consider the pros and cons of stand alone machines compared to computer dedicated programmers. ETI has previously featured constructional articles on programmers for various home micros, has recently presented the ETI Stand Alone EPROM Programmer and now seems to have come full circle by advocating use of PC specific products. So, what is the ideal solution? As always, it's a case of 'horses for courses'. Table 1 is a feature by feature comparison of the two approaches to programming EPROMs.

	Stand Alone	Dedicated
Compatibility	May be connected to any computer with an RS232 interface.	Only interfaces to one computer family.
Local Functions	Copy, verify, edit, checksum etc. may be done locally.	Nothing can be done without the host computer
User Interface	Keypad and LED/LCD display	Host computer's keyboard and full screen display.
Upgrade Path	Software upgrade path normally provided to allow new devices to be supported	No upgrade path. (See note)
Price	>£500	<£250

Table 1 — Comparison of stand alone and dedicated programmers

I think that the following few comments adequately sum up the pros and cons of stand alone and machine specific programmers. In a dedicated industrial application where EPROMs are to be copied all day long, the stand alone programmer must win in terms of both simplicity of use and economics, since the price of a machine specific programmer would immediately rise by the price of the PC which is fully utilised for this task.

If on the other hand, we are dealing with a development environment where a computer would not be fully used for programming it all comes down to whether there is a need to program from more than one type of computer. In the case of such a requirement then the cost of a stand alone machine could well be less than the price of a programmer for each of the various computers. A more common requirement, to be able to connect to a variety of machines, is to provide continuity when changing computers.

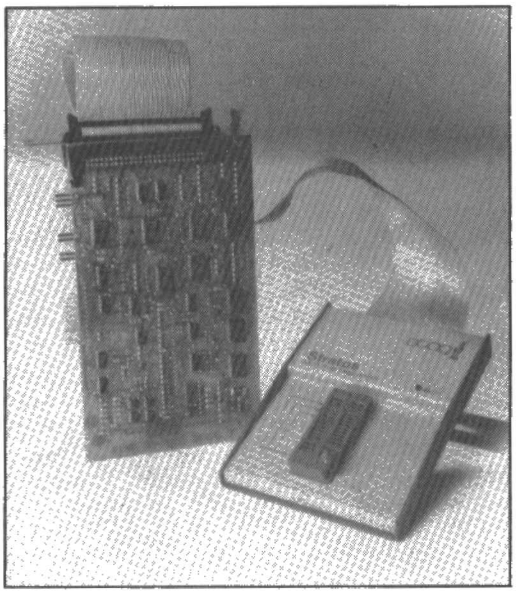
The lifetime of many of the early home micros was sufficiently limited to have made a stand alone programmer an attractive proposition. The PC, on the other hand, is a mature product with the promise of a long future and compatible upgrade path, all of which makes the use of an EPROM programmer specific to this range of computers a viable proposition.

So now to the specific products which are the subject of this article. Each programmer will be described individually and to close a table will compare salient features in order to allow easy comparison.

Stag Stratos

Initial impressions were favourable both in terms of presentation and of the quality of manufacture. The Stratos consists of the interface card, the programming site, a floppy disk and installation instructions which are attractively packaged in a moulded Styrofoam carton with cardboard outer sleeve. Surprisingly, no operating manual is included but the philosophy is that use of a pop-down menu presentation and on-line help obviates the need for such and I certainly wouldn't argue with this premise.

The PCB is a half length card designed to fit into an 8-bit expansion slot of a PC or PC/AT and everything is surface mounted except for one chip, an inductor and two user-configurable links. The programming site connects to the PCB via a 50-way ribbon cable which plugs into an IDC connector on the card's rear panel. It is of a robust metal construction and houses a 32-way ZIF socket and a single LED to indicate 'busy'. Unfortunately the ribbon cable isn't quite long enough to reach to the front of the PC but the programming site could be accommodated either on top of the PC cabinet or at its side. Installation of both the hardware and software was easily accomplished by following the instructions provided.



The Stag Stratos

Turning to the operation of the programmer, the menu driven approach with context-sensitive help meant that it took me all of 30 seconds to get to grips with it! The menu showing the supported devices was quite an eye opener with virtually every known EPROM up to the 1M-bit capacity (but excluding the 16-bit wide variants which are housed in a 40-pin package) being included. EEPROMs however, are not included. Unlike many of the home programmers which have had a single algorithm for each generic type of EPROM, the Stratos allows not only the device type but also the manufacturer to be selected. Even though the differences in the recommended manufacturers are subtle, use of the correct algorithm can increase the programming yield by a percent or so.

Another nice touch is detection of devices plugged in the wrong way round or offset in the socket, a situation which would otherwise be fatal to the EPROM. I suppose it is now a standard feature in newer programmers, but never having used a machine with flash programming algorithms before, burning a 27512 in 15 seconds proved quite a novelty. I should just point out here that with this type of programming method where the pulses are much shorter than previously used, the speed of the host processor becomes very significant to the overall programming time. The timing I quoted was on a 12MHz AT, it would take somewhat longer on a 4.77MHz PC.

On the reverse side of the coin (there always has to be something) is the fact that the software does not have a split facility for use with 16-bit code whereby odd addresses are directed to one EPROM and even addresses are programmed into the other. Of course this problem can be overcome by use of a dedicated software package on the PC (if you happen to have one) to split the object file into odd address and even address files before entering Stratos.

To finish my summary on this product, a word about importing data from disk. To provide compatibility with the output of most assemblers, files in either Motorola S-record or Intellec format may be accessed by the software. In both cases the standard and the extended (16-bit) variants are accepted. Data read from an EPROM and/or edited by the Stratos system software may be similarly dumped to disk.

So, how much is this little lot going to set you back? The bottom line is £249 + VAT and Stratos is available directly from Stag Microsystems at Martinfield, Welwyn Garden City, Herts. AL7 1JT. Telephone: (0707) 332148.

EW-901BN

Manufactured by Sunshine Electronics Ltd, this is the first of two Far Eastern products distributed by Chipboards Ltd which are reviewed here. In passing it is also worth pointing out that Chipboards have a number of PC add-on cards which may be of interest to those with a hardware leaning, a welcome change from the run-of-the-mill memory expansion, RS232 interface and video cards normally encountered.

I have to admit that before using the EW-901BN, its price had led me to expect a very much less sophisticated product than the Stratos. Furthermore on first catching sight of the manual, which is typical of that of many Taiwanese products, having a slightly amateurish appearance and using a somewhat unconventional approach to the English language, I felt that my expectations were to be confirmed...

First impressions, however, can be quite misleading. The package contains the same constituent parts as the Stag programmer but with the addition of the aforementioned manual. The less than half length interface card has not been manufactured using up to the minute surface mounting techniques but is nevertheless of a high standard. The ribbon cable is a bit longer than that on the Stratos allowing the

```
                         Stag - STRATOS
--- Device selected ---------------      ---------------- Function Menu ---
Device Type      : 27C010                L - LOAD RAM from Device.
Manufacturer     : AMD                   P - PROGRAM Device.
                                         B - BLANK Check Device.
--- Device and Address Limits -----      V - VERIFY Device.
RAM Start        :    000000             C - CHANGE to new Device.
Device Start     :    000000             O - OPTIONS.
Device Stop      :    01FFFF             S - SET Device Limits.
I/O Format       :    Intellec.          D - DISPLAY RAM.
-----------------------------------      E - EDIT RAM.
Address limit of RAM    : 01FFFF         F - FILE Functions.
Address limit of device : 01FFFF         Q - QUIT Stratos.
------------------------------ Instructions ------------------------------

Select choice using cursor keys or by pressing the first letter of your
choice.

 For Help move cursor onto subject and press F1

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```

Screenshot of the Stratos EPROM programmer

programming site to be situated at the front of the PC. This extra length, coupled with the fact that there are less conductors in the ribbon, (something which hints at less screens), could mean this product is more prone to the occasional error — I haven't used if for long enough to say for sure. On the other hand, it could just be that Stag are exponents of the 'belt and braces' philosophy!

The acid test of course, is how it stands up in action, so armed with the manual the hardware and software were installed easily. Once again the software presents a menu format to the user and the principles of operation were quickly grasped. The programmer was proved on a number of EPROMs and once again I witnessed large devices being programmed at breakneck speeds. Not quite as fast as the Stratos, but as I've said before, Stag has the fastest algorithms and the sophistication of the software will make quite a speed difference. Stag does make the claim that theirs is the fastest programmer known to man.

So in what areas, if any, does the EW-901BN fail to match up to the Stratos? The major limitation is that the largest supported devices are 512K. So clearly if there is a need for 1Mbit devices then this doesn't fit the bill. There are also a few drop-offs among the smaller devices, in particular paged EPROMs like the 27513, 25-series devices (probably not a major

```
SUNSHINE EPROM Programmer V7.0
MODEL: EW-901BN (C) 1989
-------- Main Function Menu ---------
[1]: File directory
[2]: Load BIN file into Buffer
[3]: Save Buffer content to disk
[4]: Edit,Display, Print Buffer content
[5]: Change I/O base adr. of Hardware
[6]: Display loaded file information

[T]: Type number    [M]: Manufacturer
[R]: Read
[B]: Blank check
[P]: Program
[V]: Verify
[A]: [B] and [P]
[D]: Display
[C]: Compare

[S]: Assign Programming algo.
[Z]: Assign Target Zone
[Q]: Quit
-------------------------------------
Select which function ? t

* MFR.: 27/27C      * Q'ty  : 1
* TYPE: x512        * MASTER: NO.1
  VPP : 12.5V       * ALGO. : QUICK

== TARGET ZONE -- VS -- EPROM ADR. ==
start adr: 0000 -------- 0000
end   adr: FFFF -------- FFFF
check sum: 0000

---- TYPE SELECT
0.x16   25V       9.x256   12.5V
1.x16B  12.5v     A.x256HV 12V
2.x32   25V       B.x512   12.5V
3.x32A  21V       C.x512HV 21V
4.x32B  12.5v
5.x64   21v
6.x64A  12.5V
7.x128  21v
8.x128A 12.5v

<CR> back to main menu.
SELECT NUMBER ?
```

Screenshot of the Sunshine EPROM programmer

limitation) and EEPROMs (in common with the Stratos).

The other drawbacks really come into the bells and whistles category as far as the home user is concerned but may well be considered necessities by the corporate user. Firstly the careless user could well blow up his EPROM as no detection of reversed devices is provided. The other such drawback is that there is no way of specifying device manufacturer in order to exactly match the algorithm. There is a field labelled 'manufacturer' but this is misleading in that it really means device family, allowing 27/27C general EPROMs, 87C address latched EPROMs or NMC27C NS CMOS EPROMs to be selected.

Having selected the family and device, one of three algorithms can be used, they are normal (50ms fixed), intelligent (1ms pulses until verification followed by overprogramming pulse) or quickpulse (0.1ms pulses until verification). The algorithm is not automatically changed as the device type is changed so the user has to be aware of which algorithms may be used with a particular device. The results of these factors combine to give lower convenience and the likelihood of a lower programming success rate compared to the Stratos. Unlike the Stratos, the only file format accepted by the software is straight binary.

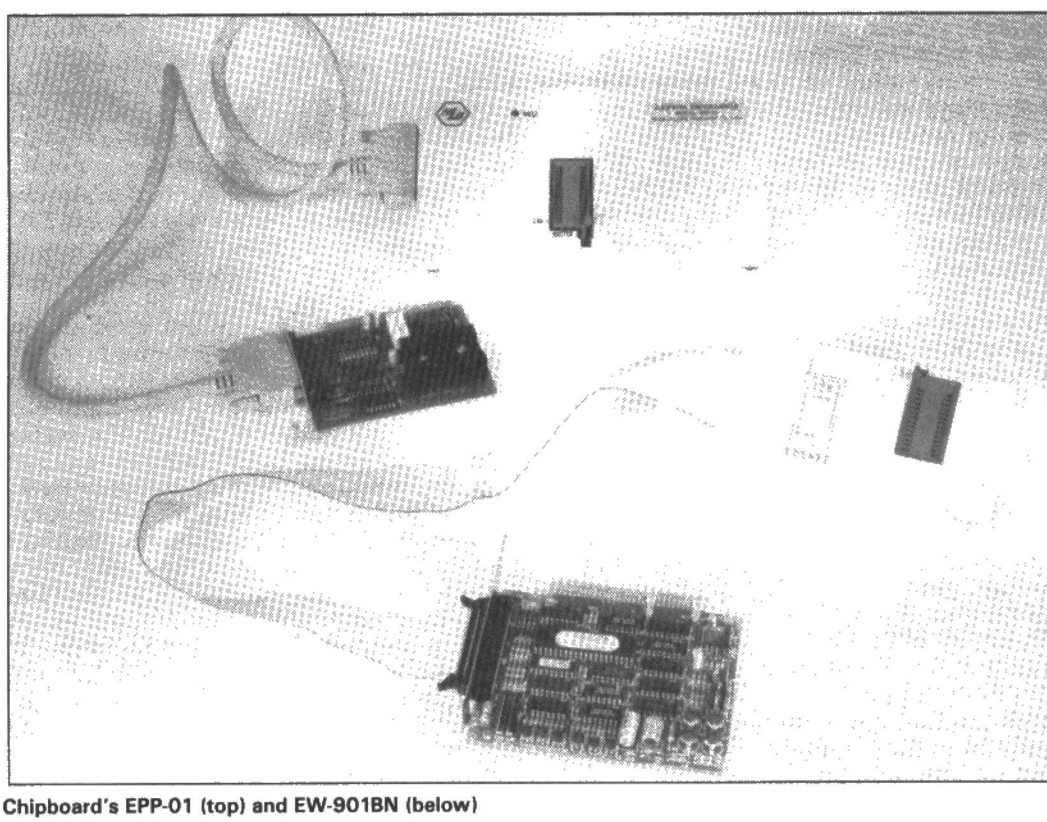
		Stratos	EW-901BN	EPP-01
Supported devices	Max size	1M-bit	512K-bit	1M-bit
	27-series	Yes	Yes	Yes
	87-series	Yes	Yes	Yes
	Paged EPROMs	Yes	No	No
	25-series	Yes	No	No
	EEPROMs	No	No	Yes
Programming method	Fixed pulse	Yes	Yes	Yes
	Intelligent	Yes	Yes	Yes
	Quick Pulse	Yes	Yes	Yes
Use of manufacturer specific algorithms		Yes	No	Suspect not
Reverse polarity check		Yes	No	No
Split facility		No	*No	Yes
On-line help facility		Yes	No	No
File format	Binary	No	Yes	Yes
	Motorola	Yes	*No	*No
	Intellec	Yes	*No	*No
	Tektronix	No	*No	*No
Produced by recognised market leader in device programmer industry		Yes	No	No
Software upgrades available		No	No	No
Price (VAT excluded)		£249	£89	£189

*External programs are provided to convert hex files to binary. The EW-901BN also includes an external program to carry out the missing split function.

Table 2 — Comparison of Stratos, EW-901BN and EPP-01

If your assembler cannot produce this output, all is not lost as a couple of external programs are provided to convert the various hex file formats (Motorola, Intellec and Tektronic) to binary.

I've already hinted at the low price of this product and in fact it can be yours for £89 + VAT. The address



Chipboard's EPP-01 (top) and EW-901BN (below)

of the importers is Chipboards Ltd., 65 High Street, Bagshot, Surrey GU19 5AH. Tel: (0276) 51441.

Tektools EPP-01

As the second offering from Chipboards, this Far Eastern product is manufactured by Hi-Lo System Research Co. Ltd. As will become obvious in the summary, this is my least favourite product.

One respect in which it does differ from the others however, is the distribution of electronics between the interface card and the programming site. In this one case the PCB has very few components with the result that the programming site contains most of the clever stuff and is therefore quite large. In many ways, the EPP-01 shares the EW-901BN's lack of sophistication. There is provision for selecting the device manufacturer but information in the manual leads me to suspect that, coupled with the device type selection, this is really only a shorthand way of selecting one of six programming algorithms. The six algorithms in question are normal 50ms, normal 10ms, normal 5ms, intelligent 1ms pulses, interactive 0.5ms pulses and quick pulse at 0.1ms. Unless I'm mistaken, what isn't taken into account is the differences in say a basic 1ms pulse algorithm to vary the maximum number of pulses allowed and the duration of the over-programming pulse, these parameters being the variant bits between manufacturers. The one area in which this product does win over the Sunshine machine is that it accepts 1M-bit devices but (in common with the Stag) only has a 32-pin ZIF socket and therefore excludes the 16-bit wide variants. Drop-offs in terms of supported devices in common with the EW901-BN are paged EPROMs. In the 25-series this is one area where the Stratos is overshadowed, EEPROMs are included. Another area in which the EPP-01 beats the Stag is provision for programming even or odd addresses only — essential for 16-bit use.

The price of the Tektools EPP-01 is £189 + VAT and once again is available from Chipboards at the address given earlier.

Recommendations

In order to ease comparison of these three products, Table 2 summarises key features of each. A few things are immediately obvious. For example, if a key requirement is programming of paged EPROMs then only the Stratos could be considered, the EPP-01 is the only one which does EEPROMs and the EW-901BM cannot be used for 1M-bit devices. These absolutes aside, it really comes down to weighing up the pros and cons of each, balancing price against sophistication.

In the small business environment I would expect the Stratos to be a clear favourite. The idiot-proofing and exact matching of programming algorithms with a consequential increase in programming yield are major considerations. The EPP-01 is certainly a bit-cheaper but a few destroyed 27010s would soon eat up the difference and at £249 the Stag is undoubtedly a lot less expensive than the stand alone alternatives.

Although £249 is not a lot to most commercial concerns, it is enough to make most home users think twice. This being so, unless one of the drop-offs mentioned earlier excludes its use, I would be inclined to recommend the EW-901BN for amateur use as it must surely be considered excellent value for money.

ETI

REGULATORS AND REFERENCES

Paul Chappell discusses the ins and outs of regulators

There was a time, and not so long ago either, when the inclusion of a voltage regulator in a power supply circuit was the exception rather than the rule. When regulators had to be cobbled together from discrete components it was only worthwhile to include one if the circuit to be powered would genuinely benefit from being provided with a specific voltage. Not so now. Regulator ICs are cheap and will be tossed into a circuit as a matter of course, whether it needs one or not. I believe that among linear ICs, regulators are second only to op-amps in volumes manufactured and sold. Which just goes to show.

Figure 1 shows the pin connections of some of the more popular types. First comes the ubiquitous 78xx series of fixed positive regulators, followed closely by the 79xx negative ones. The last two digits in each code tell you the output voltage of the regulator, so the 7805 will be a 5V positive regulator, the 7912 will be 12V negative, and so on. There's quite a wide range of voltages manufactured (you can get a 7808, for instance, to give +8V), but most suppliers limit their stocks to the most popular voltages. Both families will cope with circuits that draw up to 1A from the supply, as long as there's not too much of a voltage drop across the regulator. More about this later.

Close relations of the 78xx and 79xx series are the 78Lxx and 79Lxx low current versions, good for up to 100mA. These come in a TO92 (like a plastic small-signal transistor), so take up a lot less space than the 1A versions. Going up the scale, you can have the 'S' or the 'H' versions, giving 2A and 5A respectively. The 'S' versions are in a similar package to the 1A regulator; the 'H' types come in a TO3 style package. Some manufacturers also produce a 'T' series (3A) and a 'P' series (10A),although these are usually positive regulators only and available in a restricted range of output voltages. Just to complicate the issue, there's also an 'M' version, with the 'M' signifying different things according to who makes the IC. Sometimes it's nothing more than a 1A regulator in a TO3 package.

Figure 2 shows the reason for the popularity of regulators: they are so easy to use! With most brands of the 1A and 100mA families you can get away with just wiring the regulator itself, as shown in Fig.2a, if the load is resistive.

Turning to Fig. 2a, any regulator IC will benefit from a bypass capacitor at the output to improve transient response and cut down on the output noise bandwidth. If you're using anything other than the various 78– and 79– types, it's as well to be aware that some of the older designs will actually be unstable without the output bypass capacitor, so put one in just to be on the safe side. The input bypass capacitor is needed if the regulator is located far from the power supply board. For the 78xx, 78Lxx and the corresponding negative regulators, non-electrolytic

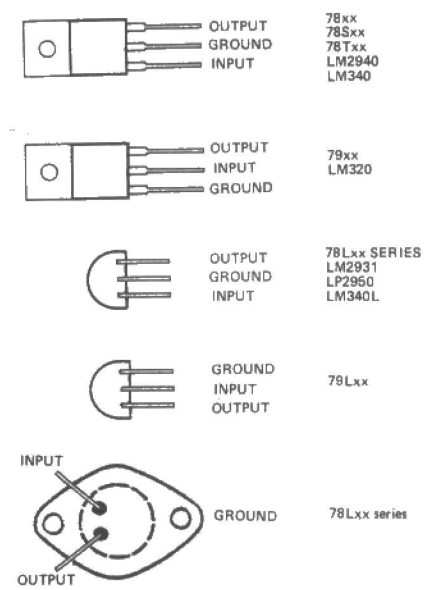


Fig. 1 Pin-outs for various families of fixed regulator.

capacitors of 470n at the input and 100n at the output will be more than enough. If you're using a regulator you're not familiar with, a 4µ tant at the input and a 10µ tant at the output will keep just about any regulator in the known universe happy.

Other Fixed Regulators

Most of the time there's not much point in looking beyond the various 78– and 79– families. They are cheap, readily available, and usually nothing more is needed. There are those few occasions, though. Here's a brief survey of the main parameters of regulator ICs.

Dropout Voltage

If you reduce the input voltage to a regulator, sooner or later the voltage drop between its input will not be enough to operate its internal circuitry, and the output voltage will drop too. With the 78– and 79– ICs, this happens at around 2.5 to 3V across the IC, so for a 7805 the output will be 5V only if the input is 7.5V or more. If the input drops below this, the output voltage will drop too. The smallest voltage you can have across the IC, below which it will stop regulating, is called the *dropout voltage*. Figure 3a shows what can happen if there's a lot of ripple or noise on the input: some of it can be passed through to the output, though by measuring the input voltage with a multimeter, you might reckon that the IC had plenty of headroom.

CIRCUIT THEORY

A regulator with a lower dropout voltage would cope with the input of Fig. 3a much better: one with a 1V dropout would regulate it perfectly. Another situation where a low dropout voltage would be an advantage might be in battery powered equipment.

If you want to regulate a 9V battery to give a constant 6V over the battery's life, a regulator with a 2.5V dropout is going to stop earning its living as soon as the battery voltage drops below 8.5V. One with a lower dropout voltage will give much longer usable life from the battery.

The LM2940 is an example of a low dropout voltage IC. The typical dropout is 0.5V, maximum 1V. Output current capability is 1A and the pin connections are the same as for the 78xx series. The LM2931 is a similar device for lower current supplies: up to 100mA output, maximum dropout voltage 0.6V, pin connections as for 78Lxx devices. Both of these regulators require a good quality 100μ output bypass capacitor — exceptions to the rule that 10μ will do for just about anything.

Quiescent Current

Not all the current entering the input terminal of a regulator finds its way to the output. Some is lost through the ground terminal. Most of the time 20mA or so going astray is no cause for concern, but for battery operated equipment this represents a considerable shortening of the battery's life. For low current standby supplies or any other circuit where drain on the supply has to be kept to a minimum, a low quiescent current regulator might be required.

The LM2931 is significantly better than most regulators with 1mA quiescent current for loads below 10mA. Beyond this you're into the realm of 'micropower' regulators such as the National Semiconductor LP2950 with 140μA ground current (T092 package, same pin-out as 78Lxx) or the ICL7663 with around 4μA ground current.

Load and Line Regulation

These should really have been top of the list, since they describe how well the regulator actually does what you're paying for: how effective it is at maintaining a steady output voltage no matter what. Load regulation is the change you get in the output voltage as the load current varies. The lower the change, the better the regulator.

Line regulation is the change in output voltage caused by a change in input voltage. Once again, the lower it is, the better the IC. This is related to, but not necessarily the same as, ripple rejection. Line regulation shows how well the IC maintains its output voltage for different fixed inputs, or for slow changes in the input. Ripple rejections shows how well it copes with faster input voltage changes. In published figures a full-wave rectifying circuit will be assumed, so the figure will be quoted for 100Hz (120Hz in American publications).

For comparison, here are some figures for the 7805. Load regulation first. If the output current changes from 250mA to 750mA, the output voltage can vary as much as 25mV (this is for a respectable brand of 7805 — the figure could be much worse for a Korean sweat-shop import). For line regulation, over the input voltage range of 7V to 25V the output can change by up to 50mV. Ripple rejection will be 62dB at worst.

To tighten up on any of these figures, an improved range of replacements for the 78xx and 78Lxx regulators is available. The 340 series give improved performance on all counts over the 78xx devices, and the 340L series does the same for the 78Lxx ICs. Pin-outs are the same as for the corresponding 78– devices.

Some regulators have special characteristics to suit specific applications. The LM2931 and 2940, for instance, will both withstand all kinds of excessive voltages that will be found in car electrical systems. If anything really unpleasant happens they shut down to protect both themselves and the circuit they're powering. Other devices have error detection circuitry that will shut down the IC if the input is low or if any other fault in the supply is detected. Others will shut down on the command of an external logic signal (for computer supplies where the software checks for errors and turns off any circuit that isn't functioning properly). Some devices will even stand being connected back-to-front, for car circuits in case some brainy garage lad decides to swap a few wires around.

The other major category of regulators is the variable voltage type. Next month for those.

ETI

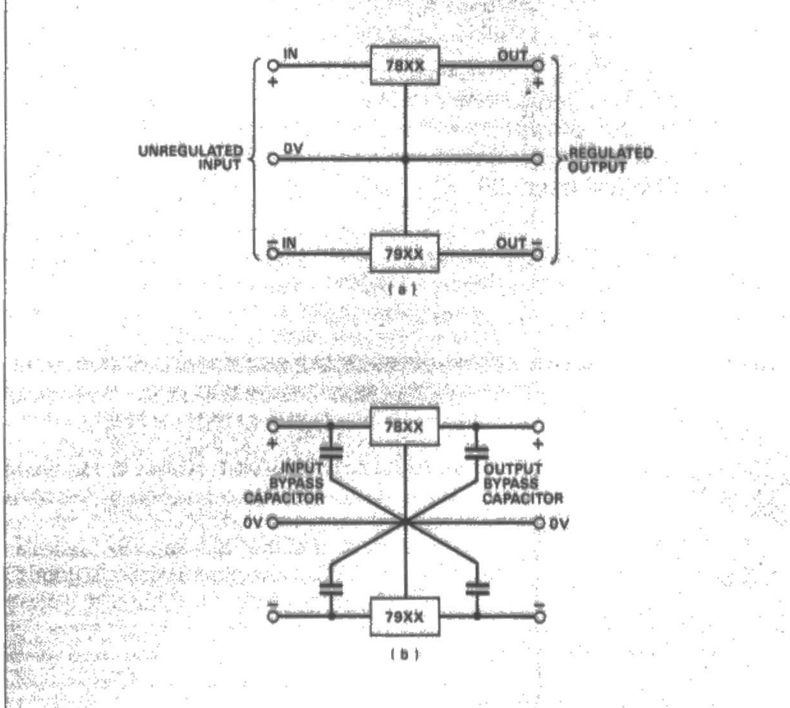


Fig. 2(a) Simplest possible regulator connection, for resistive loads.
Fig. 2(b) Regulator connection for any load. Capacitors should be wired as close as possible to the IC.

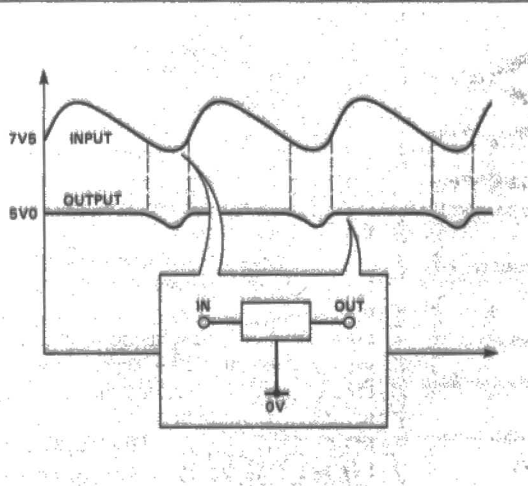
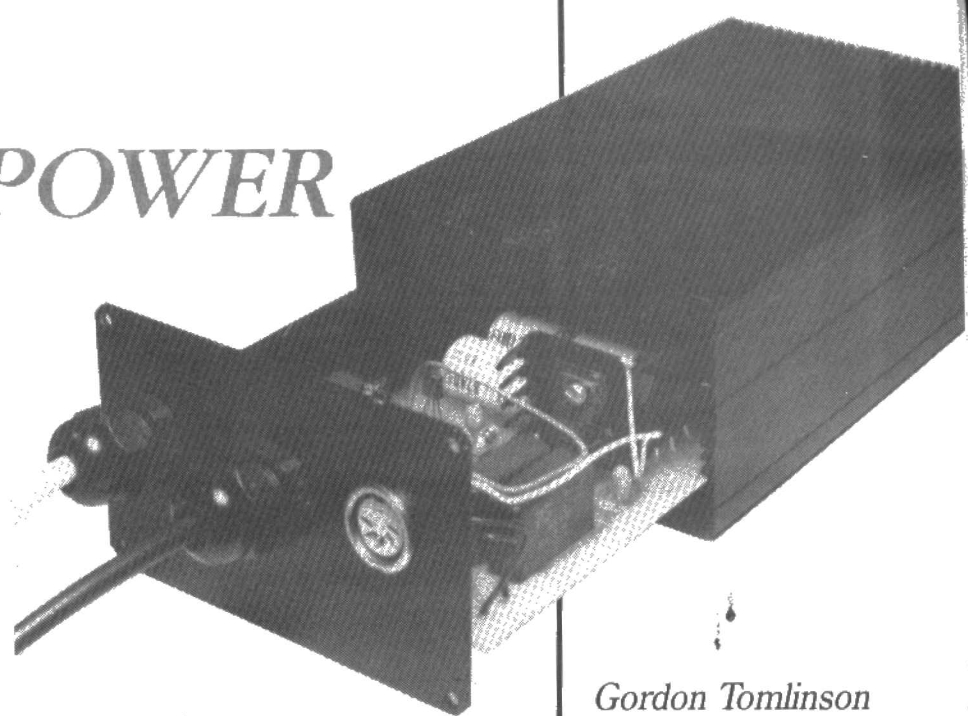


Fig. 3 Effect of dropout voltage: ripple below 7.5V is fed through to the output.

PEDAL POWER



Gordon Tomlinson shows how to cut the cabling on stage

The background to this project is quite simple. A friend plays guitar semi-pro and uses several effects pedals. He had a problem with battery eliminators and cables cluttering his stage area and so he asked for help. The solution was equally simple. A small box fitted to the rear of the amplifier providing a 8V feed for the effects pedals. This power feed and signal return became combined into a single multi-way cable and the power supply box evolved into the form presented here.

A basic design consideration is that it should fit unobtrusively into the rear of an amplifier. The unit must be compact, yet robust and so the enclosure chosen is a very sturdy aluminium extrusion that neatly houses a single 100×160mm Eurocard-size PCB. All the components mount onto the card and this simply slots into the housing.

To ensure simple operation there are only three connections to the unit. Firstly, mains power is tapped from the amplifier, preferably after the on/off switch. A second lead carries the output to the main amplifier signal input. This is soldered to the circuit board inside the main amplifier but could be provided on a flying lead/jack plug. Finally, a multiway DIN socket provides a connection to the effects pedals.

As this is an 'add-on' in a critical position, it is vital that no compromises are made in component selection. Consequently high quality components are used throughout to ensure that the unit never becomes the 'weak link' in the chain.

The input stage uses a basic differentiation amplifier to accept the incoming signal and a voltage follower to buffer the output to the main amplifier.

The power supply is configured to supply approximately 9V for the effects pedals. With reference to the circuit diagram in Figure 1, the power supply follows traditional linear supply practice of transformer/rectifier/capacitor/regulator. VDR1 is a voltage dependant resistor and zaps any large mains spikes. They are a good idea in any equipment.

The negative regulator supplies only two ICs and is a low-power type. Its output is 'shifted' from −5V to −8.9V by the application of a 3.9V zener diode to its earth terminal. This useful trick is also applied to the positive regulator. However this supplies the main power output and must be of the 7805 type.

If a good quality component with A1 amp rating is used and well heatsinked, it will happily supply 400/500mA, which is more than enough for five effects pedals. Note that regulators will only deliver their maximum rated current in cool conditions with a minimal input to output voltage drop (about 2V). The greater the voltage drop across the regulator, the lower its output current potential. Resistors R1 & R2 provide a constant load to ensure the regulators keep regulating. Capacitors C3 to C8 ensure that supplies are kept as clean as possible. It is very important to heatsink IC1 as it can become quite warm.

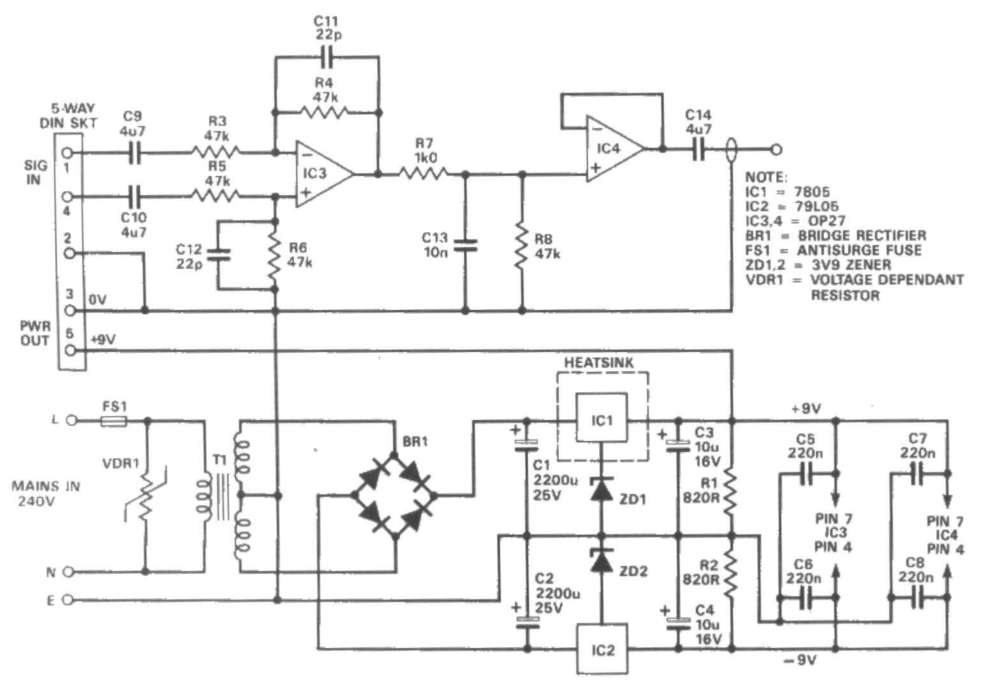


Fig. 1 Circuit diagram of power supply and input amplifier

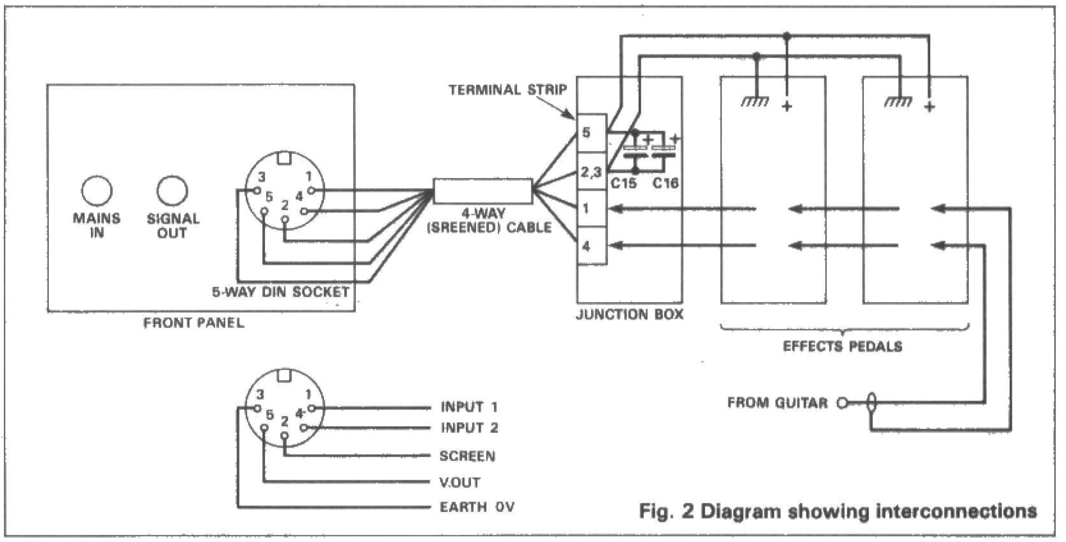


Fig. 2 Diagram showing interconnections

HOW IT WORKS

The signal handling circuitry is built around two OP27 operational amplifiers. These are quite expensive but you only need the lowest grade version.

The first stage is a basic differential amplifier. Many different formats of differential amplifier exist, and the most simple single chip version was chosen. The differential amplifier works by effectively looking at the signals presented to its inputs, and it acts in one of two ways. If the signals are different it amplifies the difference by a factor determined by R4/R3 (when R4=R6 and R3=R5). If the signals are the same then they are attenuated by the common mode rejection ratio (CMRR) of the circuit. The amount of CMRR is determined by the choice of op-amp, the auxiliary components used and circuit topology. If we had expected high levels of interference, we could have exploited the 90+ dB CMRR capability of the OP27. But we would have been forced to use closely matched (0.01%) resistors and a trimmer for C12. However in our application we do not expect high levels of interference. We can happily use 1% standard resistors. With the values shown we have an overall gain of one.

A disadvantage of a single chip stage is that the inputs are presented with unequal impedances. However this is not important here.

The network R5, C13 serves as a passive low pass filter, progressively attenuating unwanted high frequency signals. Finally the second OP27 forms a simple voltage follower (its output follows its input) and this provides a low output impedance to drive into the standard amplifier.

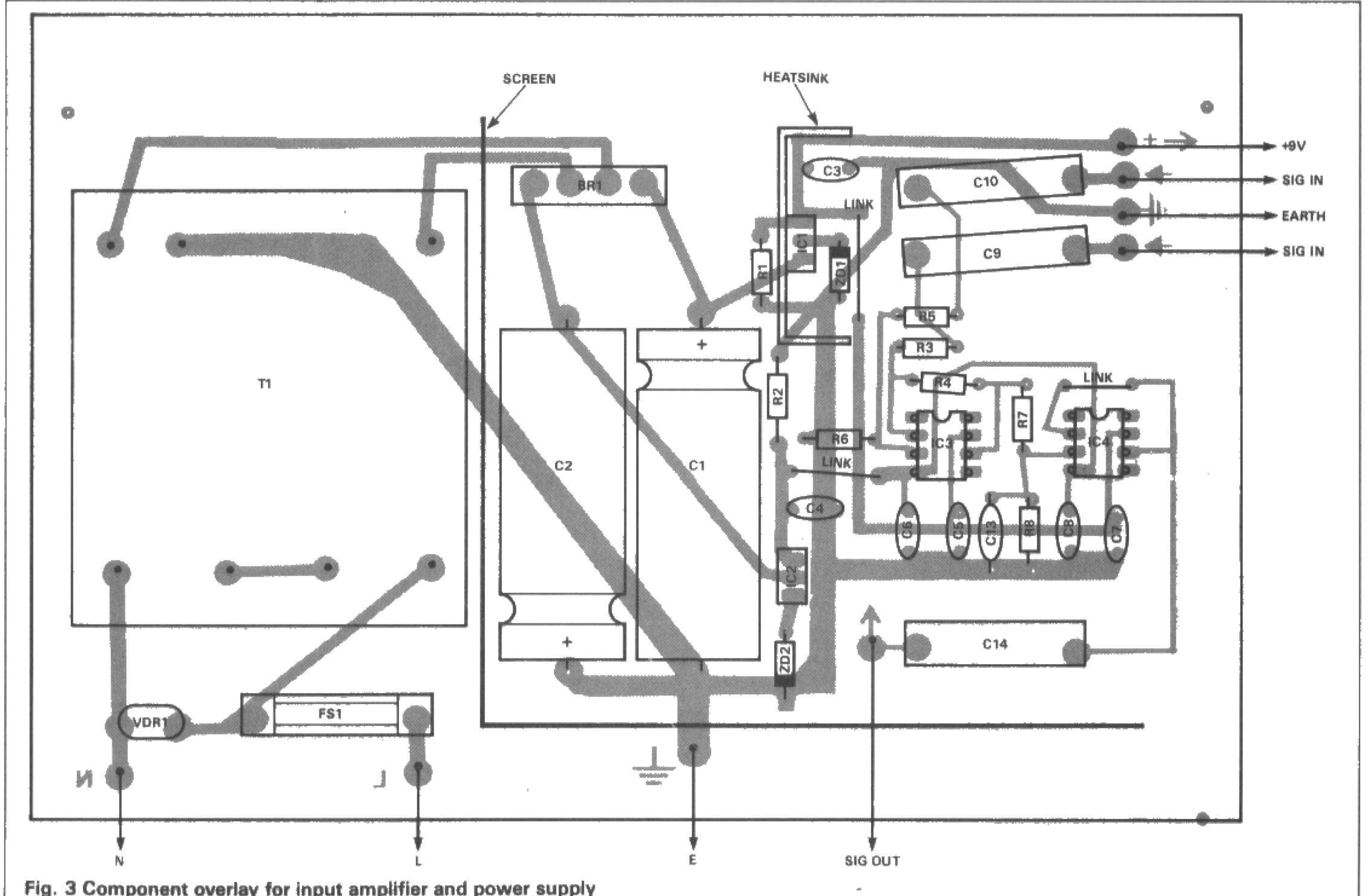


Fig. 3 Component overlay for input amplifier and power supply

Construction

The end cover of the housing must be drilled to accept the sockets and glands. This is the only metalwork involved unless you decide to make a small divider to keep the mains cable away from the other circuitry.

Basic board construction follows standard practice. Start with the small components and work your way through to the larger items, finishing with the transformer. When finished have a break and then recheck everything, especially components that are polarity conscious.

Wiring the unit to the outside world is quite straight forward and is just common sense as shown in Figure 2. The 9V power supply and signal returns are taken by a single multiway cable to the five pin din connector. You may prefer something more beefy and expensive such as an XLR connector.

How you interface the signals at the pedal end is up to you. Remember to keep cable lengths to a bare minimum. Two important points to note: capacitors C11 and C12 are soldered piggy back to resistors R4 and R6 and capacitors C15 and C16 are used at the pedal end of the line.

Getting Going

If you own a scope or signal generator then testing will probably be second nature. If you do not and run into a problem, the first thing to check is the power supply. Do you have mains? Are the regulators correctly oriented? Do you have voltage at the IC supply pins? If you are using IC sockets, have you plugged them in the wrong way? It is basically a simple circuit and should not be hard to fault find.

Where and how you fix it in the amplifier is up to you. Make sure that it is secure and not too close to the hot bits. Do not be tempted to compromise on component quality. If the main amplifier has a capacitor at its input it will be possible to remove capacitor C14. Over to you . . .

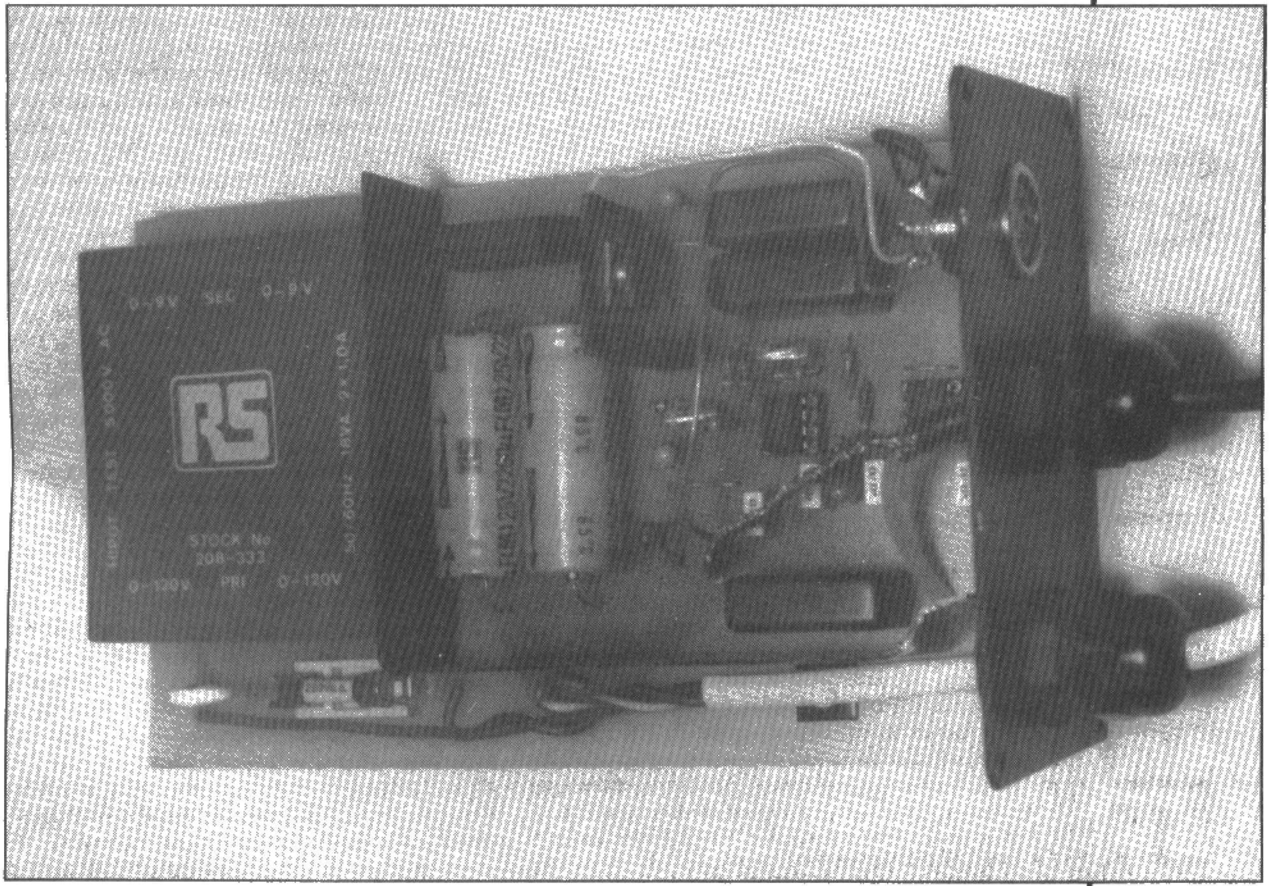
PARTS LIST

RESISTORS (all 1% metal film ¼W)	
R1,2	820R
R3-6,8	47k
R7	1k
CAPACITORS	
C1,2	2200µ 25V electrolytic
C3,4,16	10µ 16V tant
C5-8	220n plastic film
C9,10,14	4µ7 polycarbonate/film
C11,12	22p polystyrene, close tolerance
C13	10n plastic film
C15	100µ 16V electrolytic
SEMICONDUCTORS	
IC1	7805
IC2	79L05
IC3,4	OP27
ZD1,2	zener diode 3.9V
VDR1	voltage dependant resistor
MISCELLANEOUS	
BR1	diode bridge 1.5A
FS1	250mA anti-surge
T1	9-0-9V 18VA

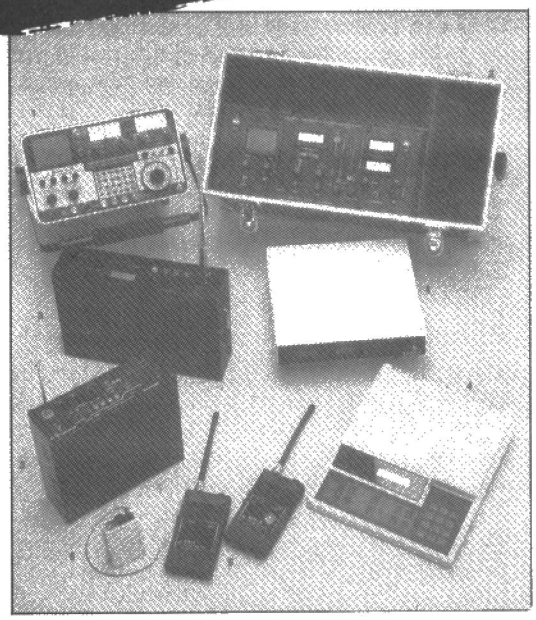
Cable & glands. 5 pin din skt and plug. Heatsink for IC1. Alloy screen. Fuse holder. Case.

BUYLINES

The parts are not cheap but they are easily available. The transformer is RS/Electromail catalogue number 208-333. Tel: (0536) 204555. The alloy case is available from West Hyde Developments Ltd. Tel: (0296) 20441.



UNDER SURVEILLANCE



Professional surveillance gear available from Lorraine Electronics' Systems-elite branch

4: Counter Surveillance

Paul Chappell sniffs out the bugs with this simple locator

SURVEILLANCE

On the cover of this month's mag you should have found a bag of components. Inside is a transistor, a 220 R resistor, a 220k resistor, a 27p ceramic, a 47p ceramic and a 2n2 ceramic (which might be marked '2200' — its value in pF).

On next month's cover there will be a PCB, and once you've got that you'll be set to build this year's free project: a VHF surveillance transmitter. A bug. Not only that, but by dividing the board into four pieces you'll have the PCBs for a complete surveillance and counter-surveillance outfit: a radio bug, a bug locator and two other radio devices. Want to know what they are? Just wait and see!

There's such a lot of ground to cover that I'll get underway this month with the construction of the bug locator. Those of you keen to get started on this can go out and buy the components and use the foil at the back of the magazine as a template. So put your transmitter components to one side and wait for the PCB next month.

Bug Locator

Once you've built next month's circuits and seen how very easy it is to bug a room or a telephone, some uncomfortable ideas might cross your mind. The first might be: 'If it's this easy for me to do it to someone else, wouldn't it be every bit as simple for someone else to bug me?' Followed by: 'Hell's teeth! What if somebody actually *is* bugging me?' There's one way to find out. Build a bug detector.

The circuit for this project is shown in Fig. 1. It's not the most sophisticated circuit in the world, but this can actually be an advantage. Since it detects the RF field without bothering to demodulate it, it matters not a jot if the bug's output is encrypted. The fact that it's broadly tuned means that it stands a fighting chance of tracking down the most hi-tech frequency-hopping bugs. And with judicious choice of diode and careful construction, it will cover not only the VHF broadcast and air bands but will extend well into the UHF bands. There's not a lot that will slip past it.

The antenna and tuning inductor of this circuit are one and the same: a strip of copper bent to a 'U' shape serves both purposes. CV1 tunes the antenna just enough to peak up the response over the chosen band, without limiting it to a narrow range of frequencies. D1 and C1 form an RF peak detector, charging C1 to a voltage proportional to the peak voltage across the antenna. Q1 gives a current proportional to this voltage and provides the oomph to drive the meter. In short, it's an RF field strength meter: the closer you get to the bug, the higher the reading

There are two things to be aware of if you're going to get the circuit to work well, or for that matter to work at all. The first is that you can't use just any old diode. It has to be up to the job of coping with the high frequencies involved (around ½GHz if you're looking at the UHF band). Schottky barrier types like the BA481 seem to work well, and have the added advantage of a low forward voltage drop which makes the meter a little more sensitive.

The second thing to bear in mind is the three rules of UHF construction: (a) Keep all component leads as short as you possibly can. (b) Never, ever leave a lead the tiniest bit longer than it has to be. (c) Make absolutely certain you follow these two rules. And so to the construction.

Construction

The antenna first. The dimensions are shown in Fig.2a, and if you have a sheet of copper to hand, off you go and bend it. If not, here are some alternatives.

First of all, you could pop down to your local hardware shop and try to get a length of phosphor bronze draught excluder strip. The seedier the shop, the more likely they are to have some. In a bright, modern shop you'll probably be offered an ozone-friendly aerosol of Draught Zap, which is no good for this project at all. Get a pair of metal shears while

you're there and a bottle of silver plating solution — there's nothing quite like a layer of silver for perking up UHF conductivity.

If the draught excluder is elusive, try to find some PCB off-cuts. Since the standard thickness of ordinary PCB laminate is 1/16in, two pieces back to back (with the copper on the outside) will give you two conductors spaced by ⅛in, which is just what's needed. The problem now is to complete the loop. Fig. 2b shows how it's done.

If there's no spare PCB material either, as a last resort you could cut the antenna from an old food can. The tin coating is nicely conductive and with its sharp edges the project will double as a potato peeler. Watch your fingers.

The tuning capacitor goes directly across the end of the antenna. No wires, OK? A trimmer may work better than a full variable cap, although it's less convenient for tuning. Fig. 3 shows one way of assembling the antenna and capacitor, together with D1 and C1 which must also be physically close to the antenna and have their leads cut right down to skinhead length.

The remainder of the components are mounted on the PCB, which itself is soldered to the tags of the meter. The component layout is shown in Fig. 4.

A screened box is required. A metal one is ideal from a screening point of view, but unless you're fairly well equipped with metal bashing tools it will be a lot of work to cut the hole for the antenna.

There are a number of other possibilities. Some suppliers stock plastic boxes with a nickel coating for RF shielding. You can also get aerosols of nickel loaded acrylic resin to give any old plastic box a conductive surface. As a last resort, you could even do a Blue Peter job on some kitchen foil and line a plastic box with that, although this will be the least effective method.

If you're using a metal or nickel coated box, the antenna entry hole must clear the antenna on all sides. If you're using the aerosol method, cut the hold before spraying the box. Cut it so that it fits the antenna snugly. Mask off an area of ⅛in around the hole with adhesive tape, then spray the inside of the box and lid. Remove the tape from around the hole and you'll have ⅛in of insulation all around the antenna. Once the rest of the circuit is assembled and the antenna is in its final position, you can give it extra support by gluing it to the box around the entry hold.

Testing And Using The Locator

About the only way to test the locator is to put it close to a bug and make sure that it does indeed register its presence. Unless you've already got one, this means waiting until next month when you can test it against the free bug. For the VHF broadcast band, the vanes of the tuning cap will have to be almost entirely enmeshed. Once tuned up against a bug transmitting in the centre of the broadcast band, the detector will cover the whole band without further adjustment.

If there's an object you think might contain a bug and you don't particularly want to break it open to find out, just hold the locator with its antenna close to the object and tune CV1 steadily from maximum down to minimum capacitance. If the needle moves at any point, set CV1 for maximum deflection and try moving the meter around. If it continues to register a signal no matter where you move it, the chances are you've picked up some strong signal from elsewhere and not a bug at all. If the deflection goes down as you move the meter away from the object and up again as you move it back, you've found a bug.

If you're going on a thorough bug-sniffing expedition, start off at the low frequency end since bugs operating in the VHF broadcast band account for by far the largest numbers sold. Then step up the frequency by opening out VC1 in four of five steps, repeating the search at each different setting. This is incredibly tedious, but the search can be speeded up no end by applying eyes and brain too.

Window frames should be inspected thoroughly: drilling a small hole through from outside will save a bugger the bother of gaining entry to your premises. Bottoms and backs of drawers, wardrobes and the undersides of any items of furniture are favourite hiding places. The fabric underside of beds: jealous lovers and spouses, blackmailers too, are large scale consumers of bugging gear, so check for any cuts or tears in the fabric where something might have been pushed inside. Ornaments, felt covered lamp bases, picture frames, and just about anything hollow could be hiding a bug. Use the meter to check anything that can't easily be opened.

Floors and ceilings and walls next. If you live in a house, the quickest way of checking the ceilings will be a physical search of the loft. If a flat or a bedsit, run the meter across the ceiling from one end of the room to the other at 2ft intervals. On floors you're looking for wires tucked under the carpet and any sign of tampering with floorboards. On walls, check for small holes, flaking paint at one point only (it's not much of a sign if *all* the paint is flaking!) or tiny cracks. If you find anything suspicious, check it out with the meter.

Now the electrical fittings: check out light switches, wall sockets, adapters, light fittings, and so on. Run the meter over the lot.

The telephone: check the phone itself, with the handset off the hook. Check out any internal fittings, junction boxes, and so on. Check the action of the hookswitch: press it down and make sure the dialling tone disappears completely. Follow the wiring from the phone and any extensions right back to the telegraph pole outside, looking for anything that

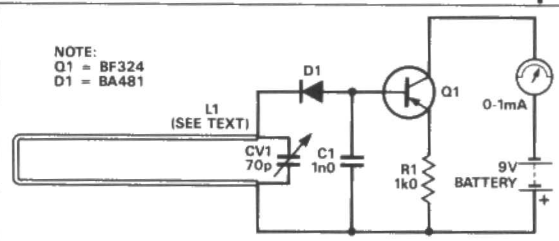


Fig. 1 The circuit

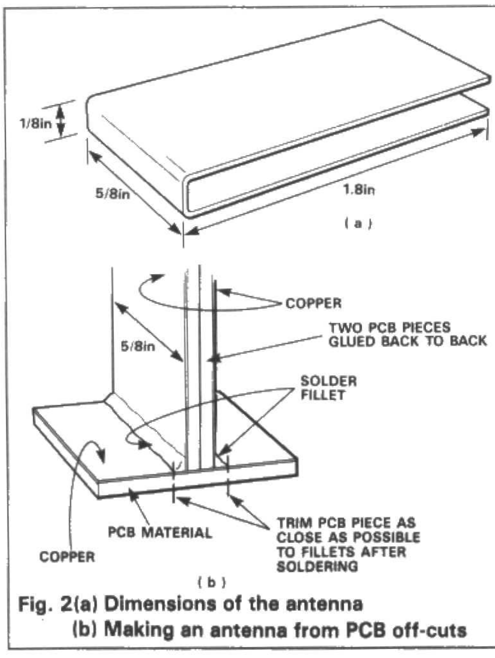


Fig. 2(a) Dimensions of the antenna
(b) Making an antenna from PCB off-cuts

SURVEILLANCE

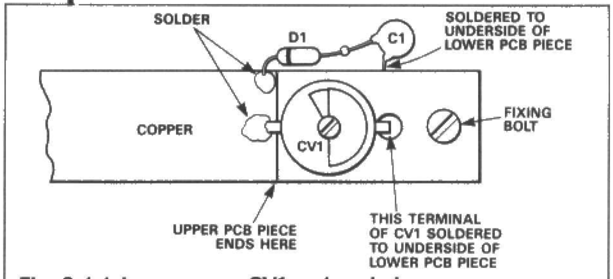


Fig. 3 Joining antenna, CV1 and peak detector

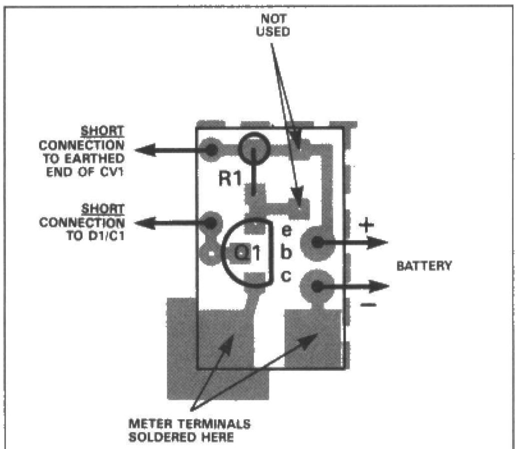


Fig. 4 PCB layout

seems out of place. Something attached to one of the wires with insulating tape, perhaps. No, other people's phones don't have those! Some phone bugs will only be activated when a call is in progress, so call the speaking clock and repeat the checks on the phone and junction boxes.

A few additional tests can be carried out with a voltmeter. Remove the cover to the box where the BT line enters your house (looking both ways for BT engineers as this is strictly forbidden) and measure the voltage across the lines. It should be around 48V, give or take a volt or two. If it's significantly lower than this, it might well indicate a parallel bug, drop-out relay or infinity transmitter across the lines. It certainly indicates that you should go over the phone circuit very carefully indeed.

With the handset lifted, the voltage should drop to around 5V. If the voltage is much above 10V, there may be something unpleasant connected in series somewhere along the line. Check thoroughly.

If you have one of the older dial-type telephones, unscrew the mouthpiece and lift out the microphone. With the meter connected across the microphone terminals, press down the hookswitch. If there's any voltage whatsoever across the terminals, your phone has been tampered with.

Although not certain to remove every single bug, these tests will detect most of the common ones. If you do find one, before ripping it out or taking any other hasty action, it's a good idea to spend a few minutes deciding just what you want to do about it. Finding out who put it there will probably be uppermost in your mind so don't yell 'Hey! I've found a bug!' If anyone's listening in at the other end, it tends to give the game away.

With a battery operated device, you can test its freshness by checking out the supply voltage. Quietly. If the battery is dead, the bugger may be long gone. On the other hand, he may try to come back and change it. If it's a live one, the chances are it's been planted, or at least serviced, within the past day or two. Bugs tend to suck their batteries dry within a matter of days.

One ploy is to try to get the bugger to come back and change the battery. If he's been there once, and hasn't yet got what he wanted, the chances are he'll return. Removing the battery is not the best scheme — if the bug suddenly goes dead it will arouse suspicion. On the other hand, connecting a resistor of 100 R across the battery with a pair of croccy clips will soon drain it, and the fading away of the signal will make it seem that the bug has died from natural causes.

With any kind of radio device, the listener won't be too far away. You can get a rough idea of the range of the transmitterby looking at the transistors used, the length of the antenna and the operating frequency. If you've discovered it with the meter, you can deduce from the tuning roughly which band the bug is operating on. A VHF bug with a short antenna points to your neighbour or someone listening in a parked car just down the road - it won't transmit far.

As for what you do when you find the bugger, you'll just have to ask him politely to stop it. Won't you?

ETI

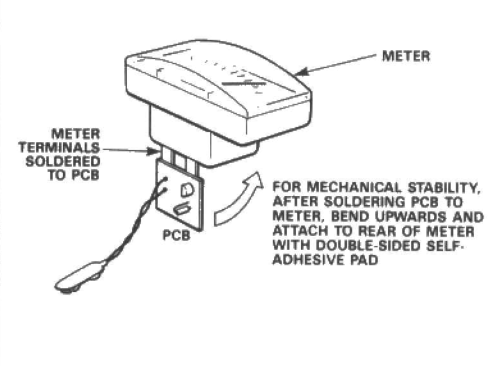


Fig. 5 PCB mounted on meter terminals

PARTS LIST

RESISTORS (all ¼W 5%)	
R1	1k0
CAPACITORS	
C1	1n0
CV1	5-70p variable
SEMICONDUCTORS	
Q1	BF324
D1	BA481
MISCELLANEOUS	
L1	4in x ⅝in copper strip (see text)
M1	1mA meter movement

Battery connector, PP3 battery, case, PCB (see next month's cover!), on/off switch.

BUYLINES

The Cirkit catalogue is a useful one to have for RF gear and components. For details of how to get hold of one tel: (0992) 444111. Components specially related to this and next month's project are available from Highgrade Components. Tel (0600) 3715 any afternoon for a list. It's free!

DIGITAL NOISE GENERATOR

Edward Barrow creates a big noise for effect

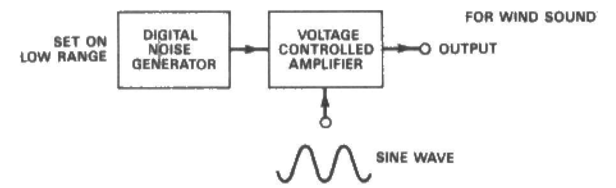


Fig. 1a Block diagram to create a wind sound

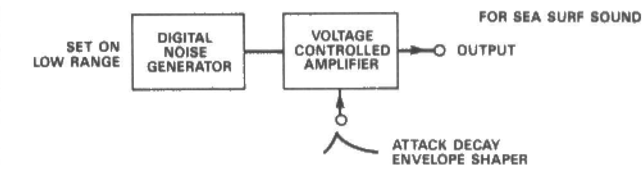


Fig. 1b Block diagram for a sea surf sound

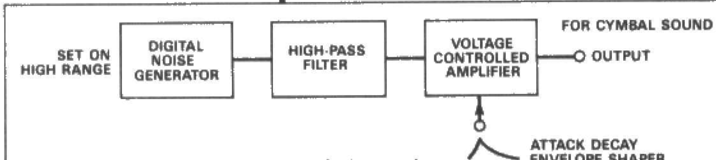


Fig. 1c Block diagram for a cymbal sound

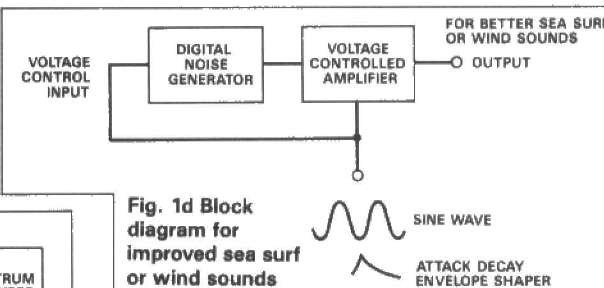


Fig. 1d Block diagram for improved sea surf or wind sounds

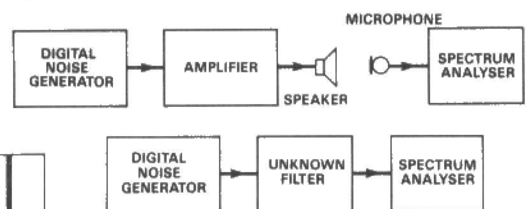


Fig. 1e Testing audio and filter responses with the noise source

PROJECT

Electronic noise sounds like hissing steam or the fuzz after the television station has been shut down. It is generated in all electronic circuits. Normally great efforts are made to reduce it to a minimum but this article shows how to create it.

Noise is analogous to light so noise containing all audible frequencies at equal power is called white noise, as white light contains all colours of the spectrum. Similarly pink noise contains more low frequency sound (equal power per octave) as red light has a lower frequency than other colours. So what use could noise have?

It is extensively used in synthesisers to produce a host of sounds ranging from wind and sea to cymbals. The block diagrams in Fig. 1 show the various combinations to produce these effects. More exotic effects can be achieved with Fig. 1d where the noise generator is voltage controlled.

Digital noise generation is popular as it gives a large and reliable output compared with its analogue counterpart which is usually made by deep fat frying a transistor or diode. If you want low frequency noise, high gains are required when creating analogue noise. Ony the clock frequency has to be lowered to produce digital noise with a lower output.

The digital variety usually involves a shift register and one or two exclusive OR (XOR) gates. Two output taps from the shift register are usually XORed and the output is fed back to the input (see Fig. 2). For this type of generation, only certain lengths of register with specific taps can be used. These are listed in Table 1. This arrangement gives a series of pseuds random 0s and 1s at the output. It is not truly random as the cycle is repeated every $2^n - 1$ clock cycles, where n is the length of the shift register.

It is important that the all zeros state is excluded as this will stop generation. This can be easily done by inverting the output of the XOR gate before feeding it back. In the project we use a 25 stage shift register so it repeats itself every 33554431 clock cycles.

At the maximum clock frequency (1 MHz) the repeat time is 33.5 seconds. and for the minimum clock frequency (100Hz) the repeat time will be 3.9 days.

The MF10cn switched capacitor filter is a mixed bag of analogue and digital circuitry. It contains two independent active filter blocks with independent clock inputs. To make it versatile, a few external connections are left to the user. All major types of responses can be formed with ease. They are: notch, bandpass, lowpass and highpass. Even variations on these themes can be easily made as in Bessel and Butterworth low pass filters.

As suggested by its name, the main work is done by a capacitor and an electronic switch. A few op-amps are used to tailor its performance to suit. The cut-off frequency of the filter block is dependent on the clock frequency and there are two ratios of clock

to cutoff frequency, 100:1 or 50:1. These can be selected by either tying pin 12 (IC4) low or high.

In this circuit it is set to 100:1, this allows us more room to manoeuvre in designing the anti-aliasing input and output filters. A maximum clock frequency of 1MHz will give us a maximum bandwidth of 10kHz and at a clock frequency of 100Hz, the bandwidth will be at its minimum of 100Hz.

From basic sampling theory we know that we must sample at least twice the maximum input frequency. The input filter therefore has to stop any frequency greater than half the clock frequency. The output also needs filtering as the clock appears on it in the form of steps (Fig.3). These are not fixed filters as they need to follow the clock frequency to prevent aliasing.

Apart from the analogue output, a digital output has been made available for other applications that would use randomly generated binary.

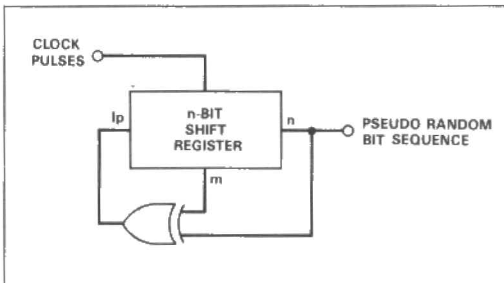


Fig. 2 Pseudo random generator using a shift register

N	M
11	9
15	14
17	14
18	11
20	17
21	19
22	21
23	18
25	22
28	25
29	27
31	28
33	20

TABLE 1. Number of bits required for shift register

HOW IT WORKS

The heart of this circuit is the digital noise generator built around IC2 & IC3 (Fig 4). These form a 25 stage shift register in which outputs at 25 and 22 are XORed to form a pseudo random bit sequence generator. The registers are clock driven and it comes from IC1 (4046). Only the internal VCO is used. The clock frequency is controlled by the voltage present at pin 9 (IC1) and it can be adjusted by turning RV1.

Filtering is required to convert this digital output to an analogue one. This is done by a 4-pole lowpass filter built using IC4, MF10 dual filter block. This filter is driven from the same clock as the noise source, so the output amplitude is constant for all values of bandwidth.

Input and output filters are required to prevent the MF10 from distorting as it is a sampling filter. These filters are voltage controlled and they track the voltage from RV1. The filters are formed around transconductance amplifiers which act like current controlled resistors and their effective resistance is controlled by the bias current entering pin 1 and 16. This resistance, used in conjunction with a capacitor, forms a simple RC lowpass filter. The buffer (IC6a) and resistor R13 act as voltage to current convertors to drive the bias current. The filter output needs to be buffered to prevent loading, this is done by IC6b and IC6. The cutoff frequency of these filters is set to about 1/70th of the clock frequency. This is adequate as the MF10 is set at 100:1 clock to cutoff frequency.

The analogue output is buffered and amplified by IC6d. This produces an output voltage of 4V.

Range switching is done by using bi-laterial switches (IC8), these switch capacitors on the VCO and on the input output filters. This lowers the bandwidth of the output. On the high range the bandwidth can be varied from 100Hz to 10kHz and on the low range from 1Hz to 100Hz.

To prevent the op-amps from clipping, a regulated 12V supply would be required. The circuit here uses a 12V supply to drive the 5 volt regulators as well as the op-amps. If you don't have a 12V supply you can either use an unregulated supply or build a small one with 100mA regulators. This project does not include a power supply as it was the thought that constructors will already have this facility on other units.

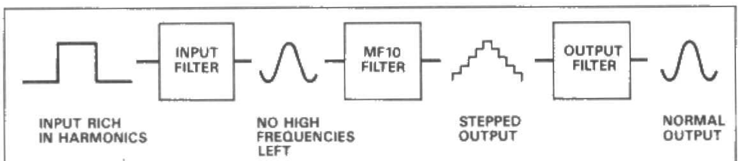


Fig. 3 Effect of filters on a step input

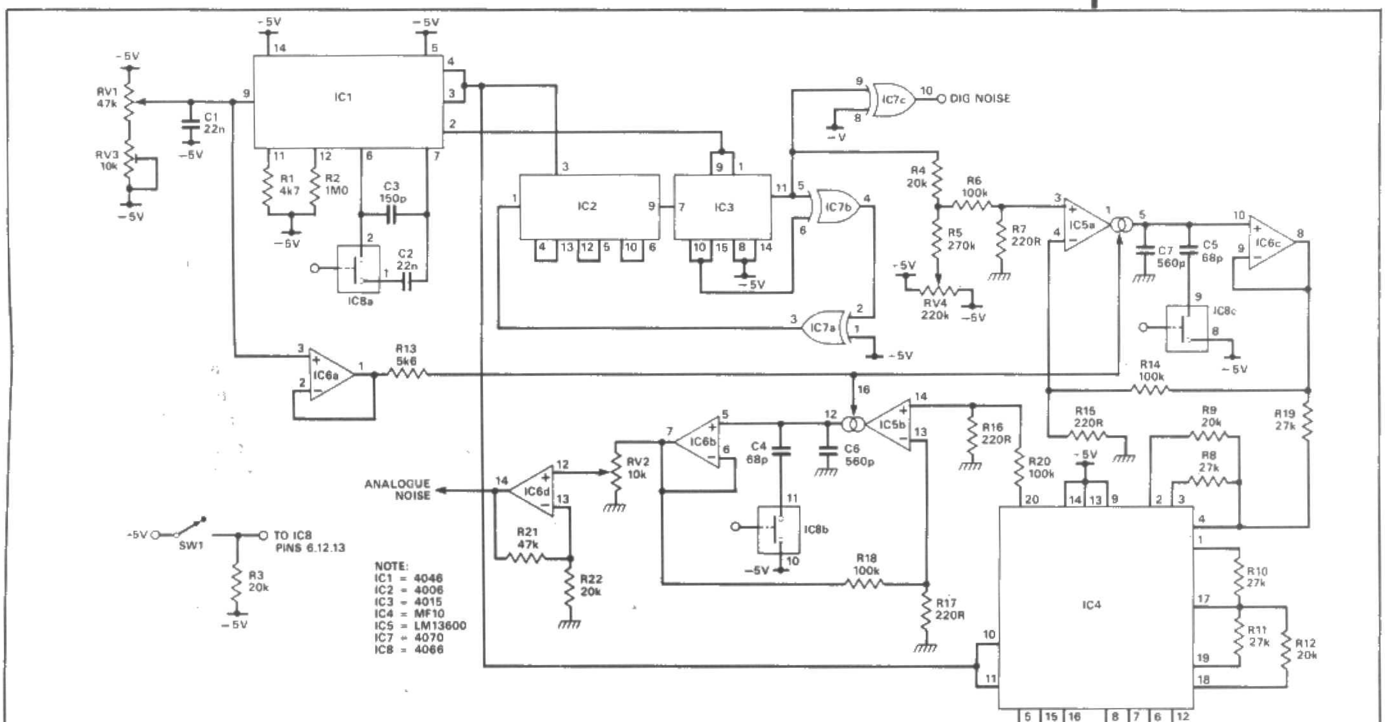


Fig. 4 Circuit diagram of noise generator

Construction

The project is a very simple one to put together. Wire links are soldered on to the board first. Next come the resistors and capacitors closely followed by the dual-in-line sockets. Flying lead connections are soldered onto the board. It can then be mounted in the case before final connections are made. Remember to take the usual precautions when handling and inserting the chips.

Setting Up

When setting up this project the following are useful: an oscilloscope, a frequency counter, and a sensitive voltmeter. If you don't have access to an oscilloscope do not dispair as a pair of headphones with a 22μ capacitor and a 1k series resistor will suffice.

Firstly set the noise generator to low range and check for oscillation with your headphones or oscilloscope (a clean square wave). Using headphones or a frequency counter adjust RV1 so that the minimum clock frequency is 100Hz (twice mains hum for headphone users). Turning RV1 fully clockwise — the clock frequency should rise to 10kHz (dog and cat owners — your pets will tell you when).

Connect a voltmeter to pin 1 on IC6 (TL084) and turning RV1 will give a varying voltage, ±5V.

Connecting your oscilloscope or headphones to the digital noise output you should see a random series of spikes or hear a hissing sound. The analogue output will be similar but spikes will be more rounded and the sound less harsh at low frequencies.

Finally any offset voltages can be removed by setting the bandwidth to maximum on the high range and connecting a sensitive DC voltmeter to the output and adjusting RV2 to zero the output.

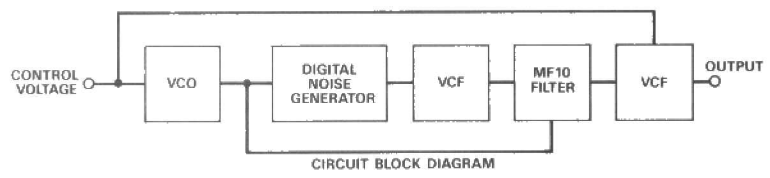


Fig. 5 Block diagram of noise generator

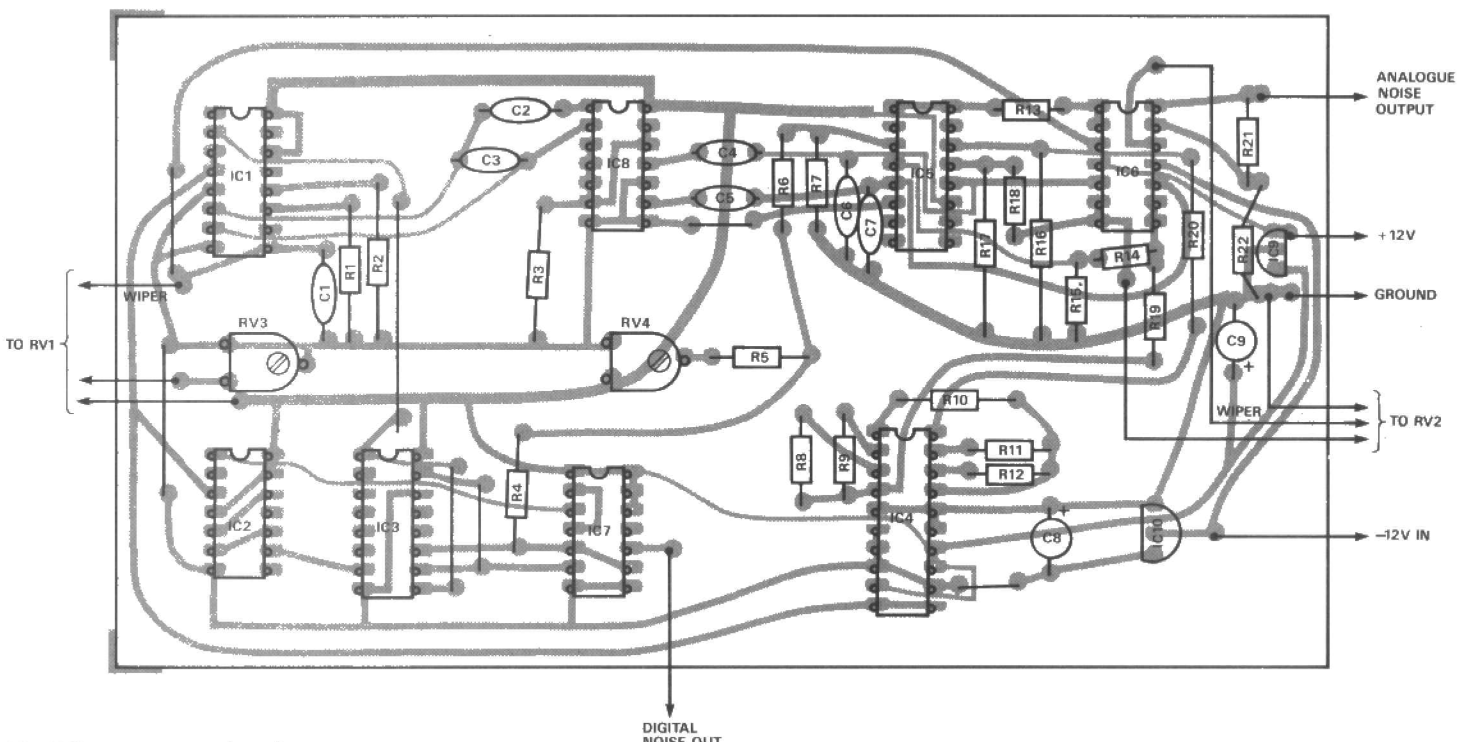
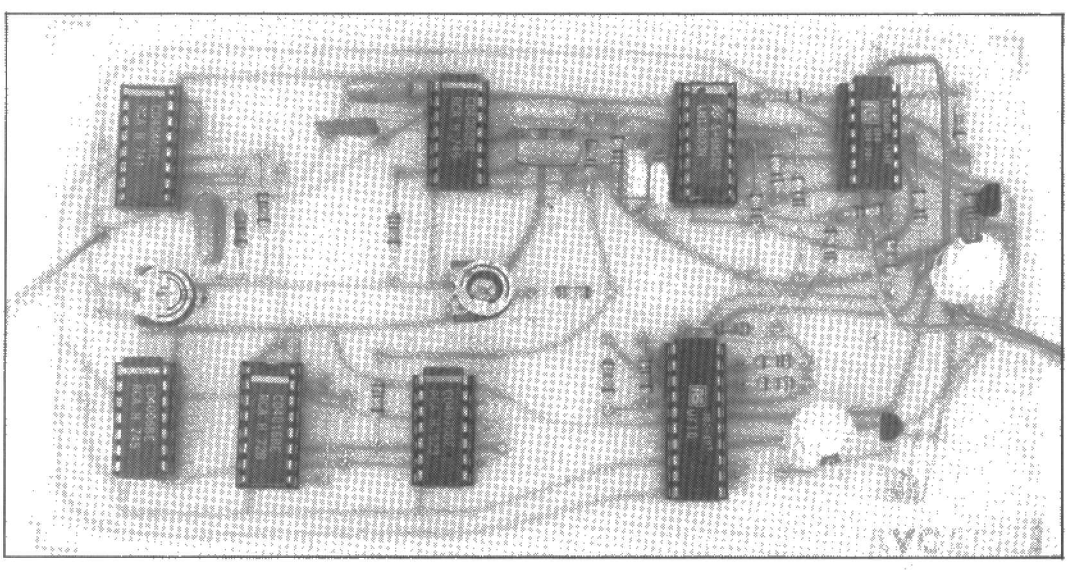


Fig. 6 Component overlay of generator



PARTS LIST

RESISTORS (all ¼W 5%)

R1	4k7
R2	1M0
R3,4,9,11,22	20k
R5	270k
R6,14,18,20	100k
R7,15-17	220R
R8,10,12,19	27k
R13	5k6
R21	47k
RV1	47k lin
RV2	10k lin
RV3	10k horizontal mounted preset
RV4	220k horizontal mounted preset

CAPACITORS

C1,2	22n min polyester
C3	150p ceramic disc
C4,5	68n min layer polyester
C6,7	560n polyester
C8,9	100µ 16V radial electrolytic

Please note that all resistors are 1% metal oxide 0.25W.

SEMICONDUCTORS

IC1	4046
IC2	4006
IC3	4015
IC4	MF10cn dual-switched cap filter
IC5	LM13600 dual transconductance amps
IC6	TL084 quad op-amps
IC7	4070
IC8	4066
IC9	78L05 +5V regulator
IC10	79L05 −5V regulator

MISCELLANEOUS

SW1	spst min toggle
SW2	dpdt min toggle

Red 4mm sockets (4). Black 4mm sockets (2). Knobs. Jack socket. Case.

BUYLINES

The 1% metal oxide resistors are generally available. Electromail have a new range of these. IC4 can also be obtained through Electromail. Tel: 0536 204555.

MAINS FAILURE ALARM

Beware the power cut, the failed fuse, the broken connection! With his beginners' project, Keith Brindley is constantly alert.

PROJECT

There are some basic household appliances which must be connected to a mains power source at all times. For them, an uninterrupted supply of power is essential to maintain correct operation. A freezer, or even a fridge, must be permanently connected to the mains: the dread of many households must be to become suddenly aware of a wet patch underneath the freezer where foodstuffs are gradually thawing out, or even to detect a smell of decaying foodstuffs where power has been lost for a considerable time. Even your common-or-garden videocassette recorder requires a constant source of mains power if the evening's edition of *Neighbours* is not to be missed (though perhaps missing *Neighbours* is no bad thing). Away from the home, it is common for tests using laboratory equipment to depend on uninterrupted and constant mains power.

It's not that the National Grid system (or whatever it may be called post privatisation) is always to blame for power breakdown. Even a simple thing such as a blown fuse, accidental removal of the appliance's plug or merely switching the power outlet off can mistakenly cause removal of power to the appliance.

For instances like these some form of alarm is useful, to monitor the applied mains power, doing nothing until a break in the supply is detected at which point an audible and/or visible indication results. The ETI Mains Failure Alarm is just that. Under normal circumstances the project sits quite happily at or around the appliance's main cable, simply monitoring that mains power is present. If for any reason that mains power is broken, the project detects this and sounds the alarm — audibly and visibly.

Designing a circuit to monitor that mains power exists is, of course, not particularly a mind-boggling feat. But the ETI Mains Failure Alarm has two features which raise it above the ordinary. First, as any circuit which is to monitor mains cannot derive its power from the mains ('cos if the mains goes off, how's the circuit going to work?), it is battery-powered. Its extremely low current consumption in the monitoring state (around 20A) means that a good quality alkaline PP3-sized battery will power the circuit for over two years — so problems regarding regular battery replacement are eliminated.

Second, the circuit does not require direct electrical connection with mains power. It monitors the fact that mains electric supply exists strictly by a non-electrical capacitive connection. This in-built safety feature ensures that at no point in the circuit does mains voltage exist.

Construction

Comprising less than a dozen components, the ETI Mains Failure Alarm really couldn't be much simpler or cheaper to build, as you'll see from the circuit in Fig. 1.

As usual in *ETI's beginners'* projects, two methods of construction are offered: PCB and stripboard. The choice of method is up to you. Details of construction don't actually vary that much. Follow the general rules for project construction whichever you decide on. Solder in all passive components first — the resistors and capacitors. Next solder in semiconductors: diodes D1-D3, followed by the LED. The integrated circuit IC1 may be soldered in but, if you prefer, an IC socket eases assembly. Finally the battery clip, piezo buzzer and 'aerial' should be soldered into your project.

Note that the aerial isn't strictly necessary if you

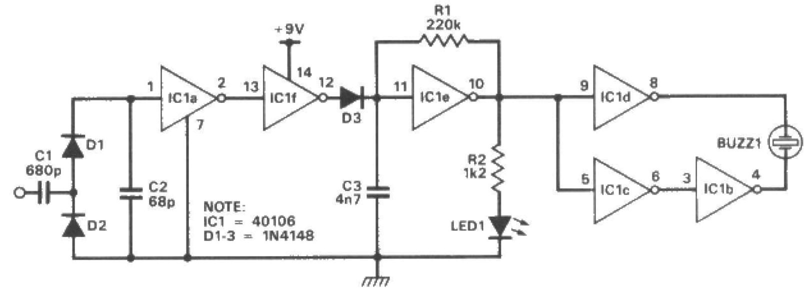


Fig. 1 Circuit of the ETI Mains Failure Alarm

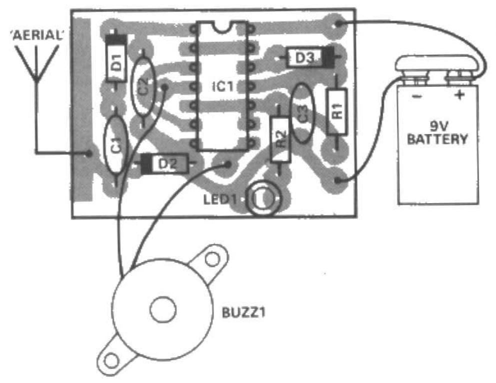


Fig. 2 PCB layout, component overlay and wiring details

HOW IT WORKS

Figure 4 shows a block diagram of project operation. For all the circuit's simplicity (refer to Fig. 1), you'll see that it comprises a large number of individual parts.

First part is a capacitive coupling to the mains cable, provided by capacitor C1 and the effective capacitance created by the proximity of the circuit to the mains cable. The metal of the input lead to capacitor C1 and the metal within the cable effectively form a capacitor (two metal plates separated by an insulator).

Next, the coupled AC voltage is rectified by diodes D1 & D2 to a stable DC voltage, detected by capacitor C2. When coupled to a mains cable carrying mains voltage, the voltage across capacitor C2 is sufficiently high to trigger gate IC1a. When a mains voltage is not in proximity, the voltage across capacitor C2 decreases to zero and gate IC1a is not triggered.

Gate IC1f forms a simple digital amplifying function, while gate IC1e and associated components form a gated oscillator. Component values of R1 and capacitor C3 as given create an oscillation of around 1kHz.

Remaining gates IC1b, c & d form an amplifier to drive the piezo buzzer in anti-phase.

PARTS LIST

RESISTORS (all ¼W 5%)	
R1	220k
R2	1k2
CAPACITORS	
C1	680p
C2	68p
C3	4n7 polyester
SEMICONDUCTORS	
IC1	40106 hex Schmitt gate
D1-3	1N4148 signal diode
LED1	red LED
MISCELLANEOUS	
BUZZ1	piezo buzzer
PCB or stripboard. Battery clip. IC socket.	

BUYLINES

All components are easily obtained and will give no problems in procurement. If your local outlet can't help, try ETI's advertisers. The PCB is available from the PCB Service as detailed on p35.

mount the complete project onto your appliance's main cable. Pickup from the cable will, in such a situation, usually be sufficient to allow successful operation. Where your project is to be mounted a distance from the cable (say sitting on top of the appliance), then the 'aerial' will be needed. In this case, the loose end of the 'aerial' should be simply coiled a couple of times around the mains cable.

PCB layout and component overlay are shown in Fig. 2, along with wiring details of external and off-board components. Similarly the stripboard construction is shown in Fig. 3.

Bear in mind that the circuit's design is such that few of the components are particularly critical, so that you don't need to go out of your way to make sure you use the exact values stated — whatever you've got in your component box will do. In fact, apart from the integrated circuit, you can mess around with all the component values to see what the result is.

Frequency of the buzzer tone for example is set by the components resistor RI and capacitor C3. Raising the value of either will lower the buzzer tone frequency.

Housing is left entirely to the reader. A small potting case will probably be sufficient, although there's no reason why the project can't even be built into the appliance to be monitored. Whatever you choose, just make sure the piezo buzzer is mounted outside the housing so that when it sounds it can be heard.

Setting Up

Fortunately there is very little to do here. A simple test will make sure your project is working properly. Place your project well away (at least 30cm) from any mains carrying cable or appliance. Connect the battery. The buzzer should sound. Now, move the project (or just the 'aerial' wire) towards a known mains carrying cable. As it gets within a few centimetres of the cable the buzzer should go quiet. If it does, your project is working. Just to check, switch off or unplug the mains cable from the mains socket outlet. Once again, the buzzer should sound.

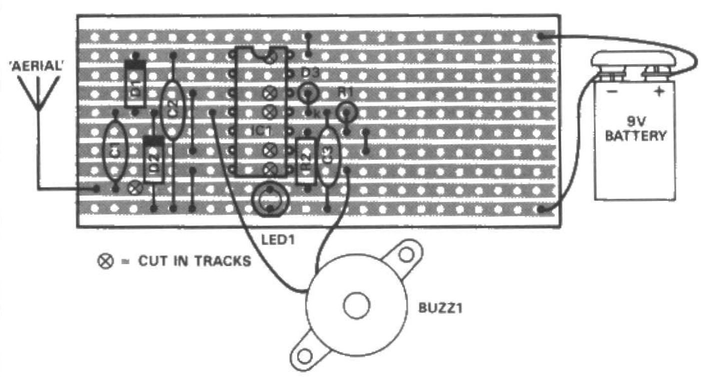


Fig. 3 Stripboard layout, component overlay and wiring details

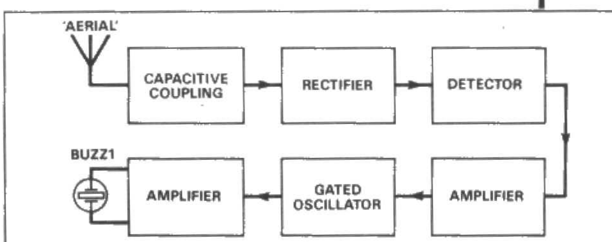
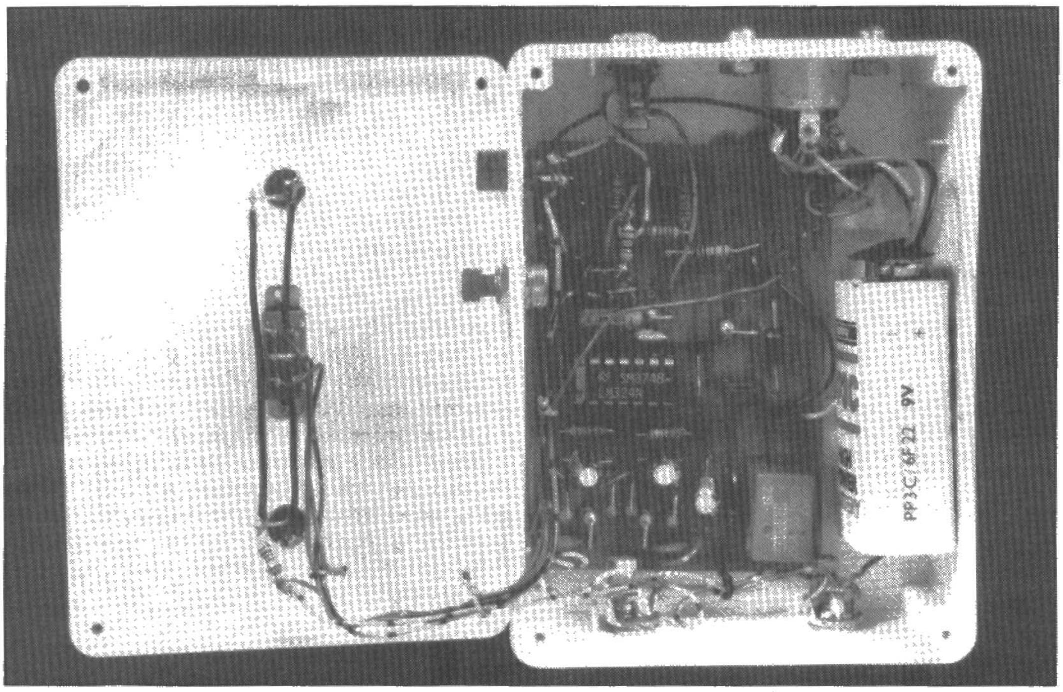


Fig. 4 Block diagram of the ETI Mains Failure Alarm

PROJECT

SOUND-SLIDE SYNCHRONISER



Chris Brown makes sure the sound always goes with the vision

It might not be as 'brill' as some of the new video effects, but there's still a small army of people around who get great pleasure from producing slide shows (or AV Presentations to give them the glossy title!). At the top end of the range, you've got the guy who uses two projectors and dissolves the slides into each other by using complex electronic gadgetry, whist at the other end of the scale you have the chap who simply talks to his audience, and presses a button when he wants the slide to change. This unit falls somewhere between the two. It makes the slides change automatically as your pre recorded tape plays.

If you consider what's required, you'll realise its a very basic piece of equipment. The circuit detects a reminder on the tape which tells it to change the slide. This reminder is nothing more complicated than a simple audio tone recorded onto the top track of the tape whilst the audio is recorded on the lower section. From this description, you can see that all we need is a device for (a) producing a tone, (b) replaying and amplifying this tone, and (c) a switch to control the projector.

We'll consider the playback mode first. There's two simple inverting op-amp amplifiers. The first is a pre amp for boosting low level signals, and the other is the main amp. Access to both amps is made possible via two 3.5mm jacks on the side of the case. The second amp is wired in such a way that the pre amp is normally connected to the main amp. However, when a jack is inserted into the socket, the output from the pre amp is cut off. The net result is to produce an output across C5 which oscillates in sympathy with the tone being replayed.

Any regular electronic buff will recognise a simple square wave generator built around IC1d (Fig. 1), but what is not so usual are the diodes connected to the inverting input via R13. With the three components listed, the tone generator will work continuously generating one long tone. By connecting the diodes to the relay coil, a positive voltage travels along this path to C7. Because C7 is now held high it cannot function, and so the generator is rendered inoperative. Once Q2 conducts, the anode end of the diode is taken low. The diodes become reverse biased and no current travels to C7. IC1d can now oscillate. The tone travels to C8 and from here out to a tape recorder and also to the base Q3 via R6. Since you cannot hear the tone, Q3 and its associated LED indicate when a tone has been generated.

To produce a tone, SW1 must be in the record position. Now when SW2 is pressed, Q1 is made to

HOW IT WORKS

Normally, resistor R10 holds the inverting input of IC1c high. Since the non inverting input is also held high, the output of the op-amp goes low. When a tone is present, Q1 conducts as each positive peak hits its base. This does two things. Firstly, it pulls down R10 making the inverting input low, and also discharges C6. When Q1 switches off, C6 begins to recharge again via R10. However, before any significant charge develops, Q1 conducts again and so the inverting pin stays low. In other words, whilst Q1 is going on and off so many hundreds of times per second, the time constant of R10/C6 makes the op amp input stay low. Of course, once the tone stops being replayed, C6 charges fully, and the inverting input goes high once more

When the inverting input is taken low, and kept low as explained, the output of IC1c becomes high. This provides base drive to Q2 which thus makes the relay operate. The contacts close, and make the projector change the slide. At the end of the tone burst which has just been replayed, the op amp swings low again cutting off Q2, and letting the relay turn off. However, a very very small current is still flowing through the coil via D2, D3, R13 and R14.

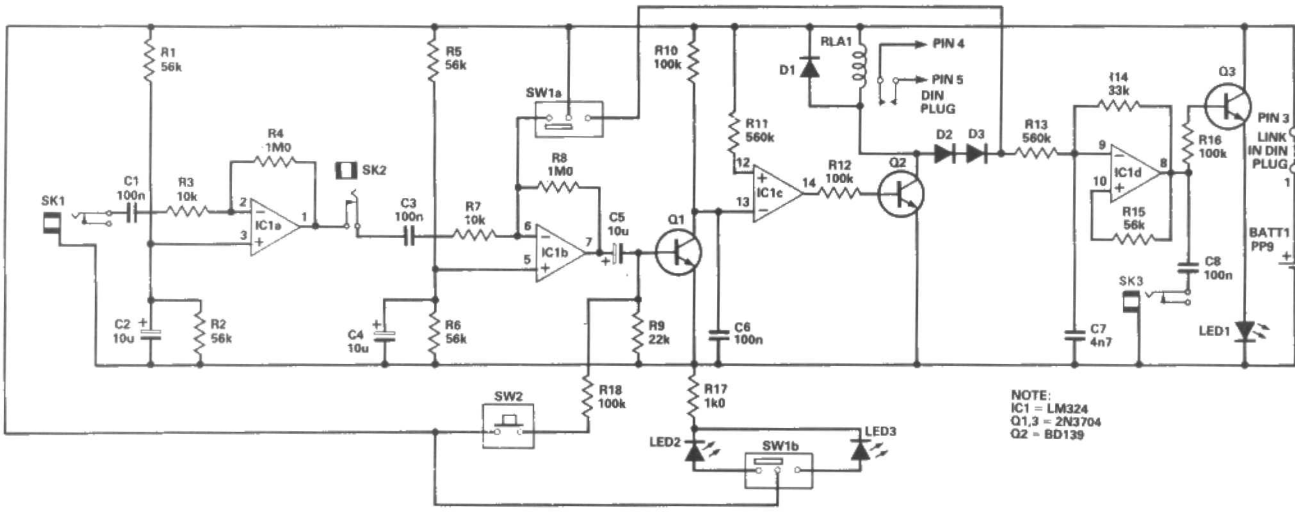


Fig. 1 Circuit diagram of sound-slide synchroniser

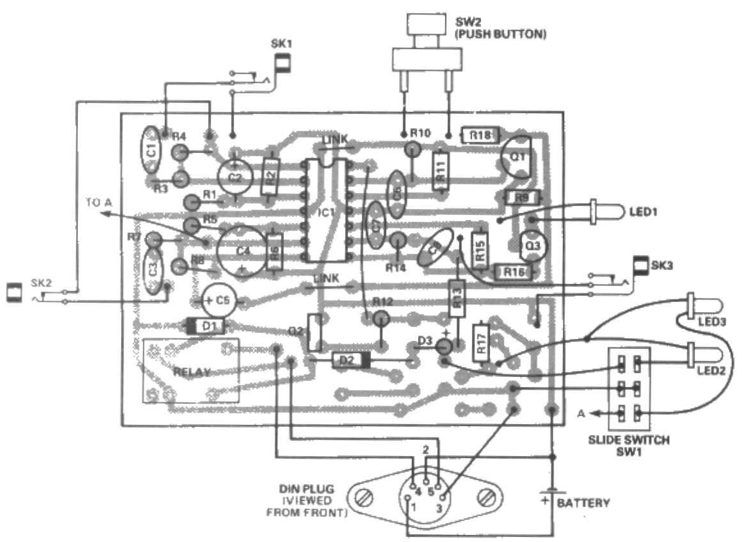


Fig. 2 Component overlay and wired connections

conduct pulling R10/C6 low making the op amp high, causing Q2 to conduct thus reverse biasing the diodes and allowing the tone to be produced. This makes the indicator LED3 light. If SW1 is in the play position, no tone will be produced, and the relay may chatter.

Switch SW1 actually switches off the tone section of the amp. Just as current travels via the relay and diodes to hold the generator off, so SW1 switches the positive line directly to R13, holding the section off. Similarly in record mode, a positive voltage is fed to the feedback network of the main amp causing its output to go low. Without this switch, the circuit forms a loop, where the tone section runs. This is fed back to the amp input and causes the tone to be produced at its output making the relay conduct. Switch SW1 also controls the two indicator LEDs on the front panel, to show which mode you're in. If LED3 lights, you're in the record mode. If LED2 lights, you're in playback mode (you only use the jacks on replay or the push button when recording!).

Construction

The board itself should present few problems, but care should be taken with all the interconnecting wires in the case. Fig. 2 shows the component overlay and external connections.

Because of the way the DIN has been laid out, no ON/OFF switch is required and an external power source can be used if required without having to take out the battery. Inside the plug which connects to the projector (SK3) is a wire link. This connects pin 1 (the battery positive) to 3 (power supply to board). So until this lead is inserted, no power travels anywhere and

PARTS LIST

RESISTORS (all ¼W 5%)

R1,2,5,6,15	56k
R3,7	10k
R4,8	1M0
R9	22k
R10,12,16	100k
R11,13	560k
R14	33k
R17	1k0

CAPACITORS

C1,3,8	100n
C2,4,5	10µ
C6	47n
C7	4n7

SEMICONDUCTORS

IC1	LM324
Q1,3	2N3704
Q2	BD139
D1,2,3	1N4001
LED1,2,3	High intensity LEDs

MISCELLANEOUS

SK1,2,3	miniature jack socket 3.5mm
SK4	5-pin DIN plug and socket
SW1	DPDT slide switch
SW2	push button switch
Case, PCB.	

BUYLINES

There should be no problems obtaining components for the Sound-slide synchroniser since everything can be ordered from the normal sources.

The case used for the prototype was from Maplin (tel: (0702) 554161), order code 3415. The PCB is available from the ETI PCB Service (see centre pages)

the unit is off. Similarly, an external power supply can be connected between pin 3 and 2, the positive and negative inputs respectively.

Operation

A lead is inserted into the tone output socket and connected to a spare track of the tape recorder. This can be either one track or a stereo recorder, an audio-visual head, or mono tape deck with an extra head added to record the top track. If using a stereo unit with VU meters, press the slide change switch (SW2) and hold down. The tone will be continuous allowing you to set a level of 0dB on the meter. With 'free head' units no setting up is needed.

There's various ways of producing your show, the most basic way being to simply chat into the mike, record your voice and press the button when you want a slide change. It has to be said this is the most amateurish way of doing it. A far better approach is to sit down, take your time and make a good master recording. If you make a mistake you can rewind that bit and do the take again. You can mix in music too if you wish. Tape made, rewind to the start, load projector and listen to the tape. When you know it's time for a slide change, hit the button. The tone will be recorded on tape, and the slide changes.

You've now got a good soundtrack, with tones recorded on the other track. Now connect the head to the playback section (remembering to flip SW1 over to playback). This is where a little care needs to be taken. If you're using a device which allows access directly to the head (without any amplification) connect this to SK2. If as is usually the case with stereo recorders, the output is from the tape pre amp section then connect the output to the main amp section. Should you be in doubt as to what type of output you have, connect the unit to the main amp first. If it doesn't work, connect to the pre amp.

There is another reason why the pulses cannot be replayed, which I can only think of as impedance mismatch. The unit built, worked perfectly with one recorder but not with another. By experimenting, it was found that a resistor placed across the input wire helped matters. I should add that this was a 'free head' that needed correcting. A stereo unit replaying via a pre amp should give no problems.

ETI

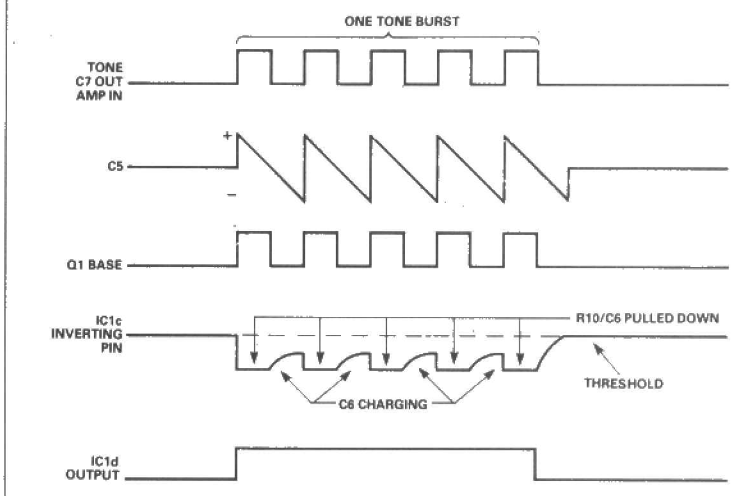


Fig. 3 Synchronising waveforms

OOPS!

Rev-Rider (January 1989)
In the Parts List RV2 is incorrectly given at 33k. It should be 22k as in the circuit diagram. A 'blob' went missing from the circuit diagram. RV2, R7, R4, C1 and D3 should all be connected.

In-car Power Supply (January 1989)
Fig. 3 shows the front view of the 317 regulator with the pin-outs reversed. The photograph, circuit and overlays are all correct showing the ledge at the front of the device.

Audio Design MOSFET Amp (May 1989)
For home constructors of the power amp PCB (Fig. 8), the copper area connecting the negative of C7, C14 and R20 is a 0V #2 connection and should be linked to the 0V #2 copper area at the junction of C16 and C18+. Hart's kit PCB has a ground plane and no mod is necessary. Note that the preset at the bottom right of Fig. 8 takes the place of an external RV3 rheostat when bench testing and is not normally required. In Fig. 7 R14 is not shown — it should be in series in the negative feedback line between C8 and D3. Also in the parts list C20 is 100uF and R9 is 2k2.

Bench Power Supply (May 1989)
In the Parts List, Q3,4 should be BC237 not BC307. The value in the circuit diagram is correct.

How To MIDI A Piano (June 1989)
In Fig. 5 the connection from pin 19 of IC8 ($\overline{MREQ}$) should go to pin 12 of IC7a, not pin 13 as shown. The component overlay is correct.

MIDI Patchbay (July 1989)
Figure 3 shows Q1-6 as npn transistors. They should in fact be pnp and their emitters should be connected to R2-12 respectively (R12 is unlabelled). Although the bases are all connected together they should not be connected to their emitters.

Reflex Action (July 1989)
Two lines in the listing on page 30 need amendment. Line 180 should read

```
180 PRINT "Enclosure volume=";vb:PRINT"tuned to";fb;"Hz":PRINT"  -3db at "; f3:PRINT "Ripple=";r;"db"
```

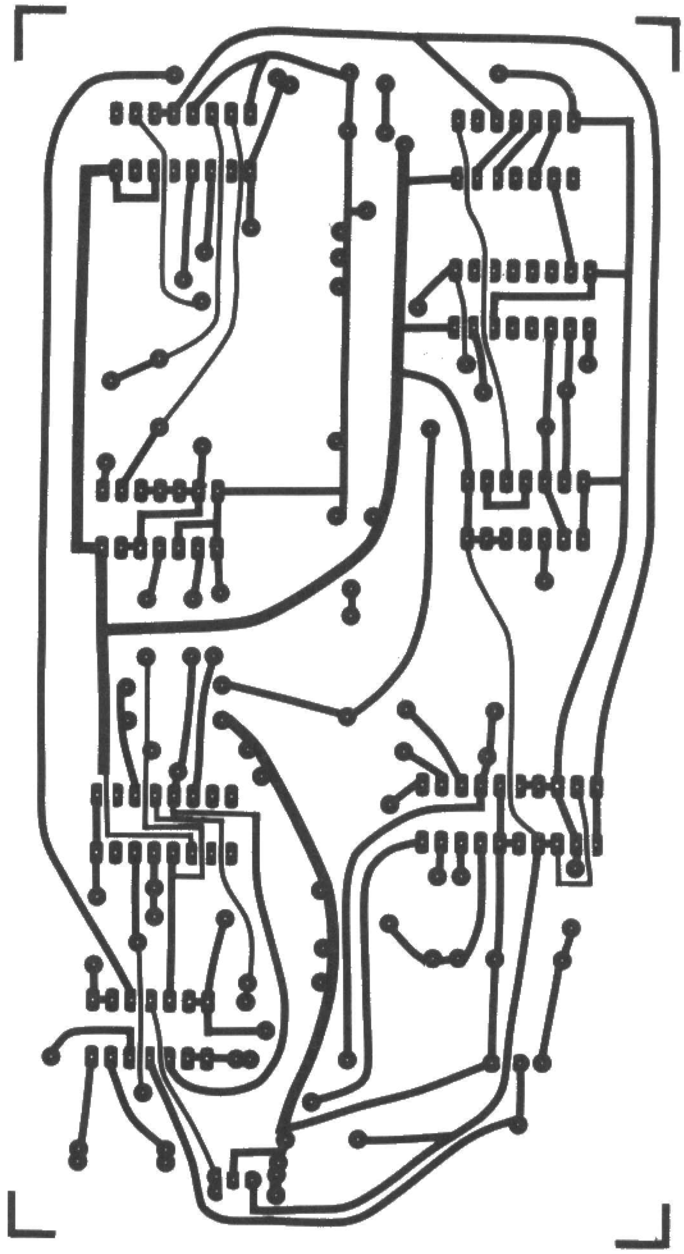
Line 280 should read

```
280 1=(2700*a)/(vb*fb 2))-0.96*(a 0.5)
```

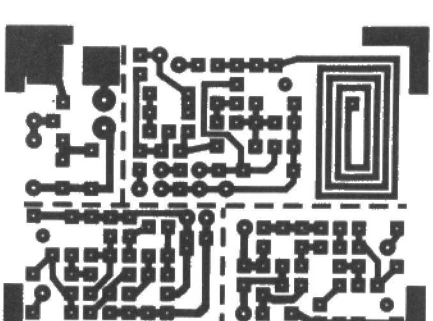
Chronoscope Revisited (September 1989)
In the paragraph headed 'Connections', D10 should read LED8 (on the sensor board). Also in Fig. 2, IC10 is shown reversed. The notch should be next to R49.

Field Power Supply (September 1989)
Figure 2 was printed with the artwork densities reversed, rendering a trifle tricky to interpret. It was reprinted together with a omitted col winding data on P62 of the October 1989 issue. A free photocopy is available from ETI Editorial on receipt of an SAE.

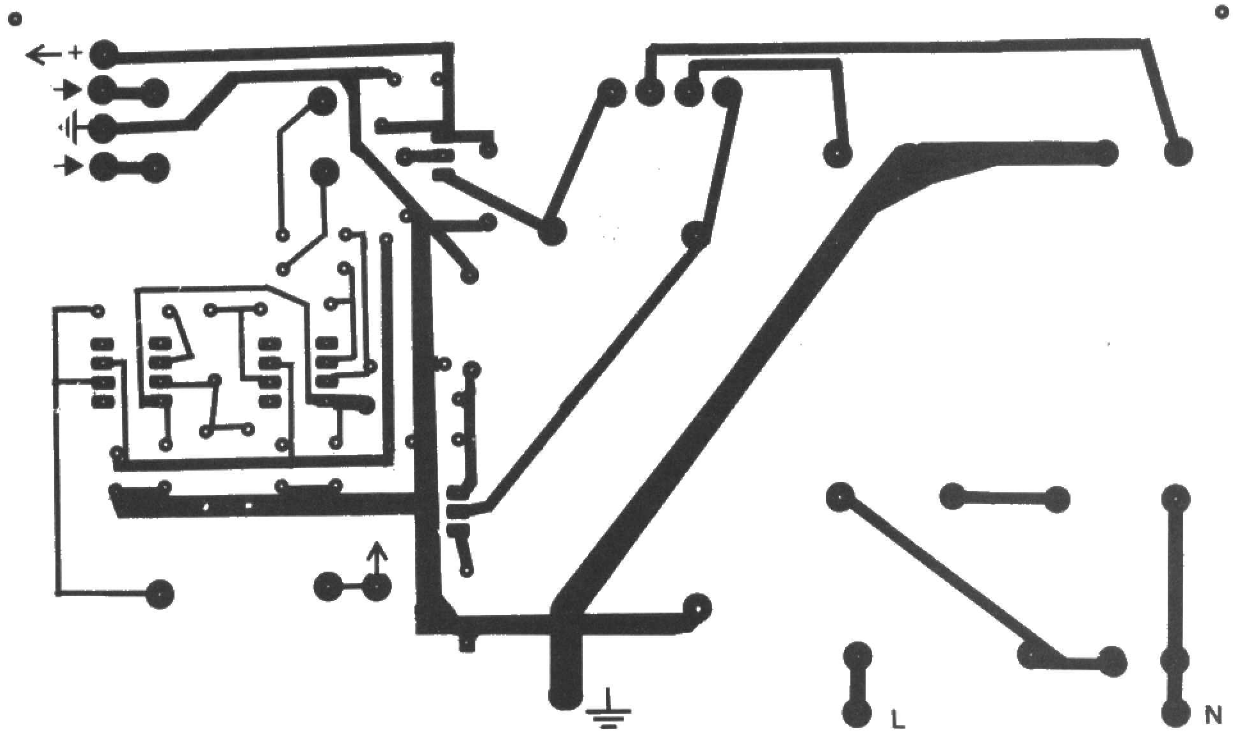
PCB FOIL PATTERNS



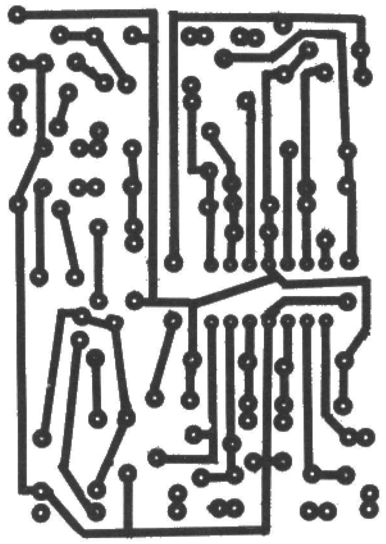
Noise generator foil



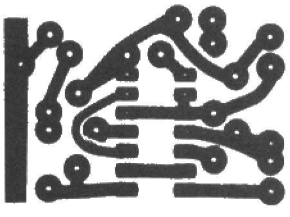
Next month's free PCB



Pedal Power main board



Slide/Tape Sync board



Mains failure alarm foil